JOURNAL OF FORENSIC SCIENCES

J Forensic Sci, November 2009, Vol. 54, No. 6
doi: 10.1111/j.1556-4029.2009.01169.x
Available online at: interscience.wiley.com

CASE REPORT

Pierre Guyomarc'h,[1,2] *M.Sc.; Maude Campagna-Vaillancourt,*[1]*; Amir Chaltchi,*[1] *B.Sc.; and Anny Sauvageau,*[1] *M.D., M.Sc.*

Skull Fracture with Brain Expulsion in a One-Level Jumping-Fall

ABSTRACT: Here presented is the case of a one-level jumping-fall with extensive skull fractures and brain expulsion. The body was found on the basement floor at the foot of the stairs. At the autopsy, the skull was extensively fractured, with about half of the brain expulsed several feet away from the body. The cause of death was established as a craniocerebral trauma with brain expulsion. The circumstances and manner of death were still unclear at that time. A low fall seemed very unlikely considering the severity of the skull and brain damage. The police investigation clearly revealed that the man, in a paranoid psychotic state, attacked his wife with a knife and then was witnessed by his children to have hit his head several times with a hammer. Afterwards, they saw him running to the top of the basement stairs and jumping to the bottom of the stairs head first.

KEYWORDS: forensic science, blunt force trauma, skull fracture, brain trauma, fall, pathology, autopsy

In falls, the mechanical force that causes injuries can be evaluated by Newton's law, $V^2 = 2gh$ (where V = velocity, g = acceleration due to gravity, and h = height of the fall). This law calculates the velocity of the body at the time of impact with the surface, which in turn relates to the amount of kinetic energy transferred to the surface. This same quantity of transferred kinetic energy is the source of injuries since it also acts in opposition to the body in motion. As g is a constant, the severity of injuries can be correlated to the height of the fall (1–3). In low falls, from 0 to 20 feet (0–6 m), head injury, forelimb fracture, and cervical spine fracture are commonly encountered (4–6) with head injuries observed most often (3,4,7,8). The most frequent head injuries are skull fractures where most of these are comminuted and/or linear with localized, depressed fractures being very rare (4). Among these fractures, the majority of them affect only the base (4,7,9). Apart from cranial fractures, often encountered cerebral traumatisms include cerebral lacerations, intracranial hemorrhage, and subdural hemorrhage (4,8,9). Brain expulsion however is virtually nonexistent in low falls.

Here presented is the case of a one-level jumping-fall with extensive skull fractures and brain expulsion.

Case Report

The body of a 43-year-old man was found lying on his back on the basement floor at the foot of the stairs (12 steps). The basement floor was made of concrete and covered by a thin carpet. The victim's legs were up, with the right toe leaned on a desk corner and the left foot leaning on a chair's armrest. The skull was extensively fractured, with about half of the brain expulsed several feet away from the body. A forensic autopsy, at the *Laboratoire de Sciences Judiciaires et de Médecine Légale* in Montréal, was requested.

The victim was 6′ tall (1.83 m) and weighed 200 lbs (90.9 kg). The skull was heavily fractured and the face was injured to the point of being barely identifiable. Apart from the head area, the remainder of the body did not exhibit signs of violence except for an abrasion on the left shoulder. Toxicological analyses were negative, including alcohol and drugs.

The scalp examination revealed eight lacerations. Two of them, one of 13 cm on the left parietal and another one of 12 cm on the frontal and right part of the face, were free of contusions and seemed secondary to the underlying fractures deforming the face and the vault bones. A wide laceration of 14 cm, with associated contusions, was located on the top of the head passing through the bregma (Fig. 1). This wound was characteristic of a violent blunt impact. The five other lacerations all displayed the same slightly curved pattern, from 1 to 3.2 cm in length. Only one of these latter lacerations penetrated through the scalp but no mark was found on the underlying bone.

The skull examination showed an important fragmentation of the vault bones and the whole face, save for the mandible, with an oblique hinge fracture of the base of the skull passing through the sella turcica from right frontal to left temporal. The fractures of the vault were radiating from the bregma, which seemed to be the major impact point. The cause of death was established as a craniocerebral trauma with brain expulsion. The circumstances and manner of death were still unclear at that time. A low fall seemed very unlikely considering the severity of the skull and brain damage.

The police investigation clearly revealed that the man, in a paranoid psychotic state, attacked his wife with a knife. After the wife managed to flee, the children witnessed him hitting his head several times with a hammer provoking an important hemorrhage. Afterwards, they saw him running to the top of the basement stairs and jumping to the bottom of the stairs head first. No marks were found on the stairs or on the stairwell walls suggesting that the victim did not hit the stairs during his descent.

[1]Laboratoire de sciences judiciaires et de médecine légale, Edifice Wilfrid-Derome, 1701, Parthenais Street, 12th Floor, Montreal (Quebec), Canada H2K 3S7.
[2]UMR 5199, PACEA (CNRS), Laboratoire d'anthropologie des populations du passé, Université Bordeaux I, avenue des Facultés, 33405 Talence, France.

Received 11 Sept. 2008; and in revised form 4 Dec. 2008; accepted 6 Dec. 2008.

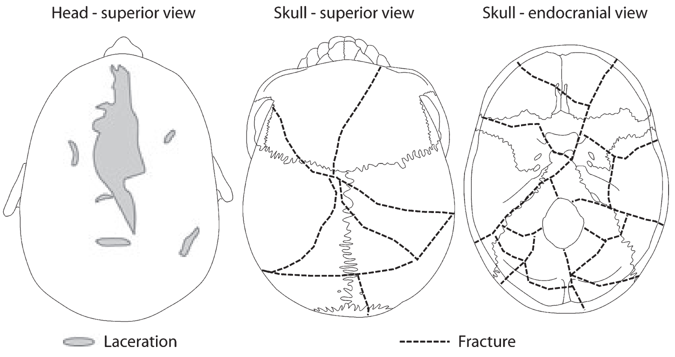

FIG. 1—*Diagrams of scalp lacerations and skull fractures.*

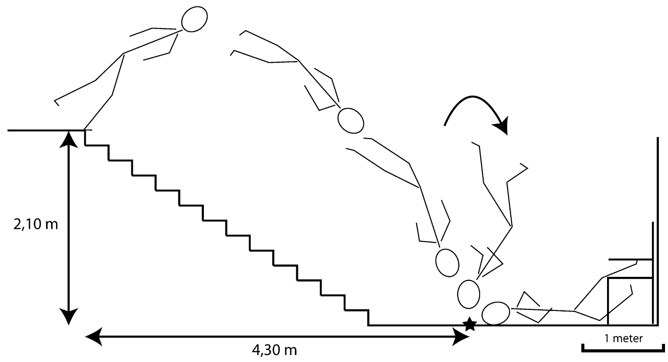

FIG. 2—*Schematic representation of the fall.*

Discussion

Upon correlating police investigation information with the autopsy findings, it was concluded that though highly unusual, this case was indeed nonhomicidal in nature, and occurred in association with a low jumping-fall in a particular context. The victim first hit his head with the hammer, at least five times but probably six times or more, and then jumped head first down the stairs. Five of the hammer blows caused distinct small slightly curved scalp lacerations. Despite that only one of these small lacerations penetrated through the scalp and that none of them left a mark on the underlying bone, these lacerations explain the scalp hemorrhage witnessed by the children. Apart from these five easily distinguishable blows, it is probable that the victim inflicted himself at least one more blow, this time weakening the skull. This sixth blow must have occurred on the top of the head, in the same area passing through the bregma that was later further lacerated and fractured in the jumping-fall. It is known that once a linear fracture has been sustained, relatively little energy applied subsequently will produce additional fractures and complete skull destruction (10). Therefore, the attractiveness of this speculation of a sixth blow is that once the skull is fractured, subsequent extension of this fracture occurs much more easily, helping to explain the avulsion of the brain.

The skull has a specific architecture that naturally protects the brain and the face's organs (11). The main components of this architecture are pillars and arcs formed by denser parts of the cranium that can absorb most shocks (12). Consequently, most of the skull fractures follow this path. In this case, however, the skull fracturing is far more extensive than generally observed.

The atypical pattern of skull fractures in this case can be partly explained by physics. The force needed to produce a skull fracture is very variable (13). Several parameters such as the stiffness of the impact surface, the height of the fall, the weight of the victim, the angle of the impact, and the localization of the impact can all influence this force (9).

One of the most important factors is the initial velocity, which is taken to be zero in simple cases of falls, but must be accounted for in jumps. This translates itself into adding the initial velocity term (V_0) to the previously mentioned formula so that it becomes $V^2 = V_0^2+2gh$. In order to calculate the initial velocity, a derived formula developed by Shaw and Hsu was used (14). The equation for calculating the initial velocity is $V_0 = (g\cdot x^2/(2(x\cdot\sin\theta + h\cdot\cos\theta)\cdot\cos\theta))^{1/2}$, with g being the acceleration due to gravity ($g = 9.81$), x is the distance of horizontal movement, and h is the height of the fall. Considering in the present case that $x = 4.3$ m, $h = 2.1$ m, and θ is about 20°, the calculated initial velocity is of 5.29 m/sec (Fig. 2). This result indicates a jump rather than a standing fall since, according to Shaw and Hsu, this velocity is too high for a standing fall (velocities below 2.10 m/sec). As for the decedent's final velocity, it was 8.32 m/sec. For a simple fall to yield a velocity of 8.32 m/sec, the fall would have to occur from a height of 3.5 m.

The action of jumping is known to imply greater injuries than falls (15), since the impact force is greater. The distinction between a fall and a jump is essential given that jumps generally refer to suicides and involve different legal consequences than accidental falls or homicides (16). In addition to the above-mentioned findings, the position of the victim's body confirms that this is a case of jumping. After the head hit the ground, the body flipped over so that the legs landed on furniture with the left toe pushed up against the chair's armrest and the right foot leaning on the desk. The jump hypothesis was thus considered to correlate accurately with the testimonies and the case was classified as a suicide.

Taken on their own, the autopsy findings would have strongly suggested a homicide. The massive fracturation can be explained by the blunt trauma preceding the jump. Moreover, the high velocity involved in the jump implies an important impact force. This case thus underlines the importance of studying the crime scene as well as exchanging multidisciplinary information between forensic experts.

References

1. Steedman DJ. Severity of free-fall injury. Injury 1989;20(5):259–61.
2. Lau G, Ooi PL, Phoon B. Fatal falls from a height: the use of mathematical models to estimate the height of fall from the injuries sustained. Forensic Sci Int 1998;93(1):33–44.
3. Atanasijevic TC, Svic SN, Nikolic SD, Djoki VM. Frequency and severity of injuries in correlation with the height of fall. J Forensic Sci 2005;50(3):608–12.
4. Gupta SM, Chandra J, Dogra TD. Blunt force lesions related to the heights of a fall. Am J Forensi Med Pathol 1982;3(1):35–43.
5. Helling TS, Watkins M, Evans LL, Nelson PW, Shook JW, Van Way CW. Low falls: an underappreciated mechanism of injury. J Trauma 1999;46(3):453–6.
6. Venkatesh VT, Kumar MV, Jagannatha SR, Radhika RH, Pushpalatha K. Pattern of skeletal injuries in cases of falls from a height. Med Sci Law 2007;47(4):330–4.
7. Preuβ J, Padosch SA, Dettmeyer R, Driever F, Lignitz E, Madea B. Injuries in fatal cases of falls downstairs. Forensic Sci Int 2004;141:121–6.
8. Bux R, Parzeller M, Bratzke H. Causes and circumstances of fatal falls downstairs. Forensic Sci Int 2007;171:122–6.
9. Hartshorne NJ, Harruff RC, Alvord EC. Fatal head injuries in ground-level falls. Am J Forensi Med Pathol 1997;18(3):258–64.
10. Galloway A. Fracture patterns and skeletal morphology: introduction and the skull. In: Galloway A, editor. Broken bones—anthropological analysis of blunt force trauma. Springfield, IL: Charles C. Thomas, 1999;63–80.

11. LeCount ER, Apfelbach CW. Pathologic anatomy of traumatic fractures of the cranial bones and concomitant brain injuries. JAMA 1920;74:501–11.
12. Félizet GM. Recherches anatomiques et expérimentales sur les fractures du crâne. Paris: A. De La Haye A, 1873.
13. Knight B. Forensic pathology. Oxford: Oxford University Press, 1991.
14. Shaw KP, Hsu SY. Horizontal distance and height determining falling pattern. J Forensic Sci 1998;43(4):765–71.
15. Teh J, Firth M, Sharma A, Wilson A, Reznek R, Chan O. Jumpers and fallers: a comparison of the distribution of skeletal injury. Clin Radiol 2003;58:482–6.
16. Cross R. Fatal falls from a height: two case studies. J Forensic Sci 2006;51(1):93–9.

Additional information and reprint requests:
Anny Sauvageau, M.D., M.Sc.
Office of the Chief Medical Examiner
7007, 116 street NW
Edmonton, Alberta
Canada T6H 5R8
E-mail: anny.sauvageau@gmail.com