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ORIGINAL ARTICLE

Discriminating factors in fatal blunt trauma from low level falls and homicide

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Abstract

Purpose Determination of the manner of death is a major issue in forensic practice. Differentiating the injuries caused by falls from a low height from injuries due to the deliberate application of a blunt object can be difficult. A few studies suggested the use of certain criteria, such as the hat brim line rule, to help in differentiating between falls and blows. Unfortunately they are not consistent.

Methods All autopsy cases from a 16-year period (1996–2012) were analyzed retrospectively. Three groups were defined: homicide cases ($n = 31$), sudden natural deaths involving a fall ($n = 103$), and accidental fall cases ($n = 30$). The three groups were statistically compared across a wide range of parameters including general characteristics, presence, and characteristics of different types of wounds (lacerations, deep bruises, fractures, intracranial trauma, and defense injuries) as well as their respective anatomical site.

Results There were marked differences in wounds between homicide and fall cases, e.g., wounds were more numerous and larger in homicides. We did not confirm the hat brim line rule as a reliable discriminating parameter. A simple and highly effective multivariate model was found, which included the presence of lacerations, deep bruises, and intracranial trauma.

Conclusion This study underlines the importance of autopsy findings in providing an indication of the manner of death. Conversely, the limitations of the hat brim line rule have been highlighted.

Keywords Autopsy · Blunt object · Fall · Homicide

Abbreviation

AUC Area under the curve

Introduction

Determination of the manner of death is a major issue in routine forensic practice. Evidence of injuries due to blunt trauma is frequently encountered in homicidal deaths [1].

Distinction between homicidal death by blunt trauma and non-homicidal deaths involving a fall from one's height or low heights such as falling downstairs (e.g., accidental deaths) can be particularly difficult. Although the characteristics of injuries that are found in cases of falls have been investigated [2], falls still remain a complex phenomena and their mechanism and implications are still not fully elucidated [3–5]. This implies that the types of injuries that may be sustained during a fall are unpredictable and variable. In the same way, various blunt objects may be used in assault, leading to various patterns of injuries. Moreover, a victim can fall during an assault.

Several studies have reported marked differences that distinguish sharp force homicidal deaths from accidental deaths [6–9], while other studies have reported differences between sharp force and blunt force homicides [10, 11]. A few studies have reported marked differences in wounds

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between accidental and homicidal deaths, according to different anatomical regions of the body [12–15]. In particular, some criteria, such as the “hat brim line” (HBL) rule, have been suggested to help separate accidental falls from homicides with blows [16–18]. The HBL rule is only based on signs located on the cephalic region. It has been investigated previously [19] and variants of it, both more and less sophisticated, have been proposed [12, 14].

The aim of our study was to identify relevant autopsy parameters that could be used to differentiate homicidal deaths by blunt trauma from non-homicidal deaths involving a fall from a low height.

Materials and methods

A retrospective comparative study was carried out on all cases from the Department of Forensic Medicine and Pathology at the Raymond Poincaré Hospital (Garches, France) from 1996 to 2012 in which forensic autopsies were performed. Cases included homicidal deaths secondary to blows (blunt trauma), accidental deaths involving a fall from low height or one’s height, and sudden natural deaths involving a fall from low height or one’s height. Cases were classified as homicidal or non-homicidal and placed into one of the three groups on the basis of all forensic elements of evidence coming from post-mortem examination and police investigation.

The exclusion criteria were as follows:

- Subject under 18 years of age.
- Body in bad condition (skeletonized, carbonized, putrefied).
- Undetermined manner of death.
- Fall from a height of more than 2.5 m.

For each selected case, the following parameters were recorded:

- Manner of death: homicidal, accidental fall, sudden natural death involving a fall.
- Gender.
- Age at time of death.
- Weight and height.
- Body mass index (BMI).
- Having fallen downstairs.
- Presence of signs of resuscitation attempts.
- The presence and the type of wounds: blunt lacerations, deep bruises, bone fractures, intracranial trauma, defense injuries, and other wounds with no role in the mechanism of death.
- The number of blunt lacerations, deep bruises or bone fractures.
- The anatomical sites of the most significant blunt lacerations, deep bruises or bone fractures, classified in five regions, in conjunction to the anterior or posterior localization: neck, thorax, abdomen, upper limbs, and lower limbs. A sixth region was used for the head, divided into three staged parts, according to the so-called HBL: above, on and below the HBL.
- The maximum size of the blunt lacerations.
- The type of intracranial trauma: subdural hematoma, extradural hematoma, cerebral contusion, subarachnoid hemorrhage or diffuse axonal injury.
- The type of bone fractures: linear, depressed fractures, diastatic or comminuted fractures.
- The presence of drugs and/or alcohol in post-mortem blood (“toxicology”).

In assaults of any kind, the natural reaction of the victims is to protect themselves. Victims can sustain certain characteristic injuries which indicate that they attempted to defend themselves. Such injuries are called defense injuries [20].

The “other wounds” category included more superficial skin injuries, such as contusions or abrasions, and not internal injuries.

The HBL definition used in this study is the same as used by Kremer et al. and Guyomarc’h et al. [13, 14]: the area located between two lines parallel to a line inspired by the Frankfort horizontal plane (horizontal plane passing through right and left porion points and the left orbitale), the superior margin passing through the glabella, and the inferior margin passing through the center of the external auditory meatus.

Data relative to measurements and number of wounds were recorded from the autopsy reports and could be compared to photographs of injuries if necessary. Reports were standardized during the time period of the study. The qualitative variable “manner of death” (homicidal death, accidental fall or sudden natural death) was statistically compared to each of these parameters using univariate analysis. For quantitative variables, either the Kruskal–Wallis test for median comparisons, or the ANOVA test for multiple mean comparisons, was used. For qualitative variables, either the Chi square test or the Fisher exact test was used.

Multivariate analyses were also conducted and different multinomial models were assessed to obtain the best combination of variables that predicted the manner of death. A stepwise method was used, and results were graphically displayed as receiver operating characteristic (ROC) curves. Multinomial models took the manner of death as a dependent variable, with sudden deaths as a reference level. Adjusted odd ratios are thus obtained for each independent variable of the models, e.g., the presence of blunt lacerations in homicide cases compared to the presence of blunt lacerations in sudden deaths.

Statistical significance was set to 0.05, in bilateral settings. Statistical analyses were all conducted with SAS 9.2 (SAS Institute, Cary, NC, USA).

Results

164 cases were selected from all autopsies performed in the department from 1996 to 2012 ($n = 6021$): 31 cases of homicide with blunt trauma (19 %) and 133 cases of fall (81 %). Fall cases included 30 accidental fall cases and 103 sudden deaths involving a fall.

Results of the univariate analysis

General characteristics

General characteristics of all included cases according to the manner of death are reported in Table 1. No significant differences were found between the three groups in terms of gender, with 58 % of males in the homicide group versus 77 % in the sudden death group and 63 % in the accidental fall group ($p = 0.08$), similarly for age, the mean age was 49 years (±18.7, range 18.5–90) in the homicide group, 51.8 years (±16.7, range 18–91) in the sudden death group, and 54.7 (±13.6, range 32–84) in the accidental fall group ($p = 0.41$).

Although differences were found concerning weight and height (individuals from the sudden death group were taller and heavier than individuals from the two other groups) there was no difference in terms of BMI.

No incidences of a fall were suspected in the homicide group. Falls down stairs were found in 47 % of the cases of the group of accidental falls.

Most cases of sudden death were due to heart disease (about 70 % of the cases, mainly heart attacks secondary to coronary heart disease), respiratory distress (about 14 % of the cases, e.g., asthma or massive pulmonary embolism), and cerebral acute pathology (about 8 % of the cases, e.g., epilepsy or cerebral hemorrhage).

Presence of wounds

Whatever their type, wounds were significantly more likely to be found in the homicide group (see Table 1), especially when compared to cases of sudden death. The presence of bone fractures was not different between homicides and falls. In particular, the presence of deep bruises, essentially located in the cephalic region (85 %), of intracranial trauma or of other wounds with no role in the mechanism of death was found in almost all homicide cases, with 100, 97, and 94 % of homicide cases concerned, compared to 47, 12, and 65 % in the sudden death cases and 63, 63, and 83 % in the accidental fall cases ($p < 0.001$; $p < 0.001$ and $p = 0.002$ respectively).

Characteristics of wounds

Blunt lacerations, deep bruises, and bone fractures were more numerous in homicidal cases (a median number of four blunt lacerations, range 1–26, 3 deep bruises, range 1–20, and four bone fractures, range 1–20 respectively) than in accidental fall cases (two blunt lacerations, range 1–4, two deep bruises, range 1–10, and two bone fractures, range 1–12 respectively), and usually more numerous than in sudden death cases (one blunt laceration, range 1–4, one deep bruise, range 1–25, and four bone fractures, range 1–26 respectively) except for bone fractures, which were found at similar frequency in homicide and sudden death cases (see Table 2). The size of the wounds was also more likely to be bigger in the homicide group.

In terms of anatomical sites, most of the blunt lacerations were found in the head area (92 % compared to 96 % in sudden death cases and 91 % in accidental fall cases, $p = 0.95$).

Bone fractures were more likely to be found in the cephalic region in the homicide group and accidental fall groups than in the sudden death group (70 and 71 % respectively compared to 18 %, $p < 0.0001$) and less likely in the thoracic area (15 and 29 % respectively compared to 76 %). Differences in the presence and type of bone fractures involved also differed, with no depressed fractures in the cases of fall or sudden death, while 37 % was found in the homicide group. Fractures in sudden death cases were all linear.

Intracranial trauma was more frequently observed in the homicide group. Nonetheless, no significant difference was found between homicides and falls for the main types of injury, i.e., subdural or extradural hematoma, cerebral contusion, subarachnoid hemorrhage, and diffuse axonal injury (see Table 2). Of the cases which had cerebral contusions (six in the homicide group and eight in the fall group), contrecoup injuries were more frequent in falls (seven cases and one case, respectively, i.e., 87 % compared to 17 %, $p = 0.02$). Conversely, there was no significant difference in terms of coup injuries when comparing homicide and fall cases (five cases and six cases respectively, i.e., 83 % compared to 75 %, $p = 1.0$). Most coup injuries found in fall cases were associated with contrecoup injuries (5 cases), unlike in homicides (only one case).

Table 1 Characteristics of the 164 cases according to the manner of death (homicides, sudden deaths, and accidental falls)

	Homicide $N = 31$ (19 %)	Sudden death $N = 103$ (63 %)	Fall $N = 30$ (18 %)	p value*
General characteristics				
Gender—n (%)				0.08
Male	18 (58)	79 (77)	19 (63)	
Female	13 (42)	24 (23)	11 (37)	
Age (years)				0.41
Mean ± SD	49 ± 18.7	51.8 ± 16.7	54.7 ± 13.6	
[Min.–max.]	[18.5–90]	[18–91]	[32–84]	
Weight (kg)				0.02
Mean ± SD	66.4 ± 11.7	73.3 ± 17	65.7 ± 15.5	
[Min.–max.]	[45–90]	[37–113]	[38.6–100]	
Height (m)				0.04
Mean ± SD	1.68 ± 0.07	1.70 ± 0.09	1.65 ± 0.09	
[Min.–max.]	[1.55–1.85]	[1.49–1.85]	[1.49–1.80]	
BMI (kg/m^2)				0.16
Mean ± SD	23.5 ± 3.5	25.3 ± 5.1	24 ± 5.8	
[Min.–max.]	[16.9–33.1]	[14–42]	[13.5–39.3]	
Signs of resuscitation attempts—n (%)				0.06
No	12 (39)	41 (40)	19 (63)	
Yes	19 (61)	62 (60)	11 (37)	
Falling in stairways—n (%)				<0.0001
No	31 (100)	98 (95)	16 (53)	
Yes	0 (0)	5 (5)	14 (47)	
Presence of wounds				
Blunt lacerations—n (%)				0.001†††/††/NS
No	7 (23)	60 (58)	19 (63)	
Yes	24 (77)	40 (42)	11 (37)	
Deep bruises—n (%)				<0.0001†††/†††/NS
No	0 (0)	55 (53)	11 (37)	
Yes	31 (100)	48 (47)	19 (63)	
Fracture—n (%)				<0.0001†††/NS/††
No	5 (16)	69 (67)	9 (30)	
Yes	26 (84)	34 (33)	21 (70)	
Intracranial trauma—n (%)				<0.0001†††/††/†††
No	1 (3)	91 (88)	11 (37)	
Yes	30 (97)	12 (12)	19 (63)	
Defense injury—n (%)				<0.0001^{+}/$^{+}$/NS
No	24 (77)	103 (100)	30 (100)	
Yes	7 (23)	0 (0)	0 (0)	
Other wounds with no role—n (%)				0.002††/NS/NS
No	2 (6)	36 (35)	5 (17)	
Yes	29 (94)	67 (65)	25 (83)	
Ethanol and other drugs—n (%)				<0.0001†††/††/NS
No	7 (23)	83 (81)	21 (70)	
Yes	24 (77)	20 (19)	9 (30)	

NS non-significant

* p values were calculated with t test for the continuous variables and Chi square or Fisher exact test for the rest of the variables. For the different types of wounds, additional pairwise P values were calculated following the form: *X*/*Y*/*Z*, where *X* stands for homicide/sudden death comparison, *Y* for homicide/fall, and *Z* for sudden death/fall

††† $p < 0.0001$; †† $p < 0.001$; † $p < 0.01$; $+$ $p < 0.05$

Table 2 Characteristics of the blunt lacerations, deep bruises, bone fractures, and intracranial trauma, according to the manner of death (homicides, sudden deaths, and accidental falls)

	Homicide	Sudden death	Fall	*p* value
Blunt lacerations				
Number				<0.0001
Median ± SD	4 ± 7.1	1 ± 0.6	2 ± 1.1	
[Min.–max.]	[0–26]	[0–4]	[0–4]	
Maximum size (cm)				0.01
Median ± SD	4 ± 5.2	2.3 ± 1.7	3 ± 3	
[Min.–max.]	[0.8–20]	[0.5–7]	[1–11]	
Anatomical site—*n* (%)				0.95
Thorax	0 (0)	0 (0)	0 (0)	
Abdomen	2 (8)	0 (0)	0 (0)	
Upper limbs	0 (0)	1 (2)	1 (9)	
Lower limbs	0 (0)	1 (2)	0 (0)	
Cervical region	0 (0)	0 (0)	0 (0)	
Cephalic region	22 (92)	41 (96)	10 (91)	
Deep bruises				
Number				0.01
Median ± SD	3 ± 5	1 ± 4.2	2 ± 2.6	
[Min.–max.]	[1–20]	[0–25]	[0–10]	
Anatomical site—*n* (%)				0.32
Thorax	2 (6)	5 (10)	2 (11)	
Abdomen	1 (3)	2 (4)	0 (0)	
Upper limbs	1 (3)	3 (6)	2 (11)	
Lower limbs	0 (0)	0 (0)	0 (0)	
Cervical region	1 (3)	6 (13)	1 (5)	
Cephalic region	27 (85)	32 (87)	14 (73)	
Bone fractures				
Number				0.03
Median ± SD	4 ± 5	4 ± 5.7	2 ± 3.2	
[Min.–max.]	[0–20]	[0–26]	[0–12]	
Anatomical site—*n* (%)				<0.0001
Thorax	4 (15)	26 (76)	6 (29)	
Abdomen	0 (0)	1 (3)	0 (0)	
Upper limbs	0 (0)	0 (0)	0 (0)	
Lower limbs	0 (0)	1 (3)	0 (0)	
Cervical region	4 (15)	0 (0)	0 (0)	
Cephalic region	19 (70)	6 (18)	15 (71)	
Type—*n* (%)				0.003
Linear	12 (44)	33 (100)	17 (81)	
Depressed	10 (37)	0 (0)	0 (0)	
Diastatic	1 (4)	0 (0)	0 (0)	
Comminuted	4 (15)	0 (0)	4 (19)	
Intracranial trauma				
Type—*n* (%)				0.43
SDH	10 (32)	3 (25)	7 (37)	
EDH	1 (3)	0 (0)	0 (0)	
Cerebral contusion	6 (19)	3 (25)	8 (42)	
Subarachnoid hemorrhage	13 (42)	6 (50)	4 (21)	
Diffuse axonal injury	1 (3)	0 (0)	0 (0)	

Fractures reported in the homicide cases in the cervical region were only fractures of the laryngohyoid complex

SDH subdural hematoma, *EDH* extradural hematoma

Table 3 Anatomical site of wounds of the cephalic region, according to regions bound by the HBL rule and according to the manner of death (homicides, sudden deaths, and accidental falls)

	Homicide	Sudden death	Fall	*p* value*
Blunt lacerations				
Level of the HBL—*n* (%)				0.28
Above	6 (27)	22 (54)	6 (60)	
On	12 (55)	14 (34)	3 (30)	
Below	4 (18)	5 (12)	1 (10)	
Deep bruises				
Level of the HBL—*n* (%)				0.17
Above	15 (55)	19 (59)	4 (29)	
On	11 (41)	13 (40)	9 (64)	
Below	1 (4)	0 (0)	1 (7)	
Bone fractures				
Level of the HBL—*n* (%)				0.13
Above	3 (17)	3 (50)	6 (75)	
On	14 (78)	2 (33)	2 (25)	
Below	1 (5)	1 (17)	0 (0)	

HBL hat brim line

* Fisher exact test

Anatomical sites of the head according to the hat brim line rule and wounds

Table 3 shows the anatomical sites of the head according to the HBL rule and wounds. No significant difference was observed between groups. For blunt lacerations and bone fractures, sudden death cases and accidental fall cases tended to show a similar pattern, being more likely located above or on the HBL.

Results of the multivariate analysis

Using a stepwise method for variable selection, we found an optimal multivariate model to predict the manner of death, homicides versus deaths involving a fall (accidental falls and sudden deaths involving a fall). This model consisted of three variables, namely the presence of at least one blunt laceration, the presence of at least one deep bruise, and the presence of intracranial trauma. The combination of these three variables was a strong predictor for homicide. The associated ROC curve showed a good area under the curve (AUC) of 0.9391, which ensured good predictive power (see Fig. 1). These results were also conserved for homicide cases versus accidental fall cases only. When comparing homicides, accidental falls, and sudden deaths in multinomial models, it appeared that the presence of intracranial trauma was the most prominent factor that discriminates between these three manners of death (OR 189, $p < 0.001$ for homicide cases versus sudden death cases and OR 12, $p < 0.001$ for accidental fall cases versus sudden death cases). When comparing only homicides and accidental falls, we obtained OR 28 ($p = 0.007$) for the presence of intracranial trauma (homicide cases vs. sudden death cases).

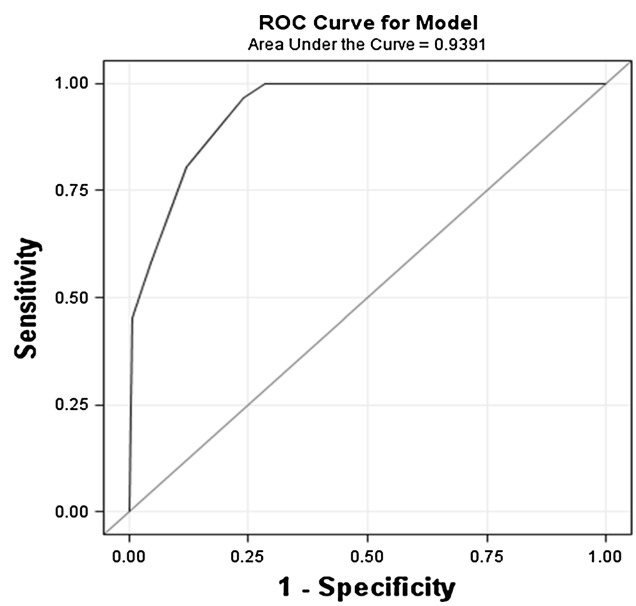

Fig. 1 ROC curve for a three criteria model discriminating deaths with a fall and homicides by blunt trauma

Discussion

This study gave us the opportunity to review and incorporate a complete set of variables to be compared according to the manner of death: accidental fall or sudden death involving a fall from a low height versus homicidal death by blunt trauma. We studied a significant number of cases spanning a large period of time (16 years).

There were limits for our study which was monocentric, and could have suffered from local specificities, e.g., it could have implied a recruitment bias compared to other French or even European regions. Forensic autopsies were carried out by different forensic pathologists, without systematic cross validation of the findings and reporting, making them operator-dependent. Practices and techniques may also have evolved during the 16 year period that our study covered. Nonetheless, autopsies were conducted daily by a small group of skilled forensic pathologists, and all autopsy reports were standardized, so that serious distortions in reporting were limited.

The number of included cases was satisfactory for the main statistical analyses, but still fell short for some specific sub-analyses, such as analysis including the different anatomical regions where wounds were seldom located, e.g., the abdominal region. Manner of death was clearly determined according to our inclusion criteria, in order to avoid any misclassifications and biases for the statistical analysis.

A strong limitation of the kind of study we conducted is the danger of circular reasoning. Indeed, studies such as randomized controlled trials are out of reach in most cases in forensic pathology and choices to assess causality are limited. The pre-existing knowledge and beliefs of the forensic pathologist when performing an autopsy cannot be ignored and are even necessary since one of his/her missions is to determine the manner of death. Nonetheless, our study is primarily a descriptive and comparative study. The so-called predictive models should not be considered under the common sense of predictive. These models are only convenient ways to identify the relative contribution of different characteristics, while eliminating those that are less (or not) relevant for discriminating between homicidal and non-homicidal deaths. At least, multinomial models can be seen as a way to reflect how important and relevant a forensic pathologist thinks that specific patterns are when the issue of manner of death is raised.

In our cohort no differences were found in terms of gender, age or BMI. Homicidal cases were systematically associated with a greater frequency of wounds, whatever their nature. It was remarkably true for deep bruises which were always present in homicide cases, and also for intracranial trauma (found in 97 % of the homicidal cases). Lacerations were also more numerous and of greater size in the cases of homicidal death: an average number of four lacerations in homicide cases compared to two in accidental fall cases, and a mean maximum size of 4 cm in homicide cases compared to 3 cm in accidental fall cases. Another significant result of our study was that the simultaneous presence of at least one laceration, at least one deep bruise, and of intracranial trauma, was highly predictive of homicidal deaths versus either sudden deaths involving a fall or accidental falls only. We did not confirm the HBL rule as a reliable discriminating parameter.

Discriminating factors between homicidal and non-homicidal deaths involving a fall

Guyomarc'h et al. [14] reported several discriminating factors to distinguish homicidal deaths compared to accidental deaths: reporting more than three lacerations, a laceration length of 7 cm or more, comminuted or depressed calvarial fractures, lacerations or fractures located above the HBL, left-side lateralization of lacerations or fractures, more than four facial contusions or lacerations, presence of ear lacerations, presence of facial fractures, and presence of extracranial osseous and/or visceral trauma, were all elements pointing toward homicidal death rather than non-homicidal death. In comparison, the range of laceration number was between 0 and four in non-homicidal cases. The range was greater in the homicide group, between 0 and 26. Our data showed that the average number of lacerations was greater in the homicide group than in non-homicidal deaths. We also found that the laceration length was greater in homicide cases than in fall cases. Our data suggested that a length >4 cm was more likely to be associated with homicide. Besides, the maximum laceration length we observed in a non-homicidal death was 11 cm (in the group of accidental falls). Depressed fractures were also most likely associated with homicidal deaths in our study (37 vs. 0 % for both sudden death cases and accidental falls).

On the basis of these discriminating factors, Guyomarc'h et al. [14] also suggested the use of a decision tree to separate homicidal deaths from accidental ones. It relied on a four steps tree, and the following factors: scalp laceration number, scalp laceration length, fracture type, and facial fracture. The authors reported that this tree could classify 82 % of falls and 93.7 % of blows correctly. This kind of tool can be useful, but may not be the simplest one in routine practice. Kremer and Sauvageau [12] suggested another set of discriminating factors: the localization of skull fractures in relation to the HBL, the side lateralization of skull fractures, and the number of lacerations, were elements in favor of homicidal deaths. The limits of these two approaches were mentioned by the authors themselves [14]. Falls showed a predictability rate that ranged between 62.5 and 83.3 %. The use of the decision tree was limited to several cases; for example: not all cases present skull fractures and, even in cases showing skull fractures, a right-side or left-side lateralization is not always present. In contrast, our combined approach seems to be simpler while presenting a very good predictability for homicidal deaths versus non-homicidal deaths. Indeed, it relies on three autopsy findings which are systematically reported. The combination of these three parameters as a discriminating criterion is in accordance with the study by Sharkey et al. [21] that experimentally established a correlation between the applied force and implement used with resultant injuries. It also reported that the minimum force for the occurrence of a laceration was 4000 N, which is more likely the case in a blunt force homicide rather than in a non-homicidal death. Of course, our combined criteria should not be used in any case, but only when homicidal deaths by blunt trauma are suspected and have to be differentiated from non-homicidal deaths that involve a fall from a low height: its predictive value is only valid in that specific case. It should be underlined that such criteria only have a value of orientation relative to the manner of death. On no account can the determination of homicidal blunt trauma be made based only on the presence of one laceration, one deep bruise, and intracranial injuries, since such findings can frequently be found in individuals who died after a fall.

The results of our study are not only of interest to forensic pathologists but also to physicians and surgeons in emergency departments. Indeed, they have to consider the mechanism of injuries, and the existence of discriminating factors could help them in this task.

Results concerning the hat brim line rule

The relevance of the HBL rule has recently been challenged [12–14] and has been shown to not be totally convincing [19], although it is considered to be sometimes partially useful [14]. The HBL rule says that scalp lacerations and skull fractures located above the HBL are associated with blows rather than with falls [12, 13, 15, 22]. In our series, the proportions of lacerations located above the HBL found in falls were approximately twice as high as the proportions observed in homicides, but this difference was not significant.

For wounds located on the HBL, lacerations are supposed to be associated with falls, while skull fractures are more or less found in similar proportions [12]. We reported the same inverse distribution for lesions located above the HBL, e.g., lacerations located on the HBL seemed to be more frequent in homicide cases than in accidental falls (55 vs. 30 %), but the differences were not significant. Attention should be paid to the difficulty to correctly classify a laceration or a complex bone fracture as above, on or below the HBL. The length of the lacerations in homicidal cases could reach 20 cm, with an average of 4 cm. Moreover, there was seldom only one laceration in such cases. To classify lacerations above or on the HBL can be a difficult task, especially when they are astride the HBL.

Fracasso et al. [19] also noted that this rule has severe limitations because it cannot be applied in many real life circumstances, such as falling from a kneeling or sitting position, falls down stairs, falls on an irregular surface, and impacts with intermediate obstacles (e.g., walls, furniture) while falling.

Other findings and comparisons with literature

We found no evidence of falls associated with homicidal deaths. It can be a great challenge for the forensic pathologist to distinguish a spontaneous fall from a fall caused by an assault.

The presence of drugs, especially ethanol, has been reported in different studies, whether in homicides [23, 24] or falls [2]. We found a high rate of ethanol use and other drugs in homicidal cases (77 %), while a meta-analysis by Kuhns et al. [23] reported an average rate of 48 % in homicide cases. Concerning falls, Hartshorne et al. [2] reported a presence of ethanol in 48 % of the cases tested, which is relatively similar to our findings. Differences in the likelihood of ethanol being present could be explained by differences in delays between the discovery of the body and the autopsy and toxicological analysis (the decomposition of the body could have affected the ethanol results), but also by the use of different thresholds in ethanol measurements. Indeed, in our series, cases were classified as positive for ethanol when ethanol was detected, whatever its blood level. Ranges of ethanol levels expressed in g/l in the different categories were, when not null [0.52–3.26], [0.12–4.82] and [0.25–3.86] in homicide, sudden death and fall cases, respectively.

Differences between sharp and blunt force homicides have been investigated [7, 10, 11]. In particular, Ambade and Godbole [11] reported that the head was the most commonly impacted region of the body in blunt force homicides, while the majority of blunt force victims showed lesions in only one region. These observations are compatible with our results since 92 % of the lacerations in homicides were located in the cephalic region, and the remaining 8 % were in the abdominal region. In terms of bone fractures, 70 % were located in the cephalic region, 15 % in the cervical region and 15 % in the thoracic region, which can be explained by resuscitation attempts.

Carson [25] also reported different patterns of lesions between natural deaths and homicidal deaths. He found that natural deaths were more likely to present bruises without any other type of lesions, whereas homicidal deaths were prone to not only bruises but also other types of lesions. Chattopadhyay and Tripathi [26] found that subdural and subarachnoid hemorrhages were present in most of fatal head injuries among assault victims, which also mirrors our findings (74 %). Mohanty et al. [27] found similar, although slightly lower, proportions (61 %). Yet, we found similar proportions of subdural hemorrhages in both accidental and homicidal cases when intracranial traumas were observed. Hartshorne et al. [2] found much greater proportions of subdural hemorrhages (85 %) among deaths by ground-level falls than we found (37 %), but most of the cases in the Hartshore study were much older than ours (only 12 % were younger than 50 years old). Many of them presented with predisposing morbid conditions.

Comminuted or multiple skull fractures were also considered as highly predictive of homicidal cases [26] as well as being found frequently [27], which is partially similar to our results, when compared to non-homicidal deaths. Indeed, comminuted skull fractures were observed in similar proportions in homicides and accidental falls. Nonetheless, it is known that traditional autopsies do not necessarily determine the number of fractures accurately when compared to imaging techniques, such as CT. Therefore, some bone fractures may have been overlooked in our cases.

Finally, despite the fairly wide range of variables that we gathered, we did not report all parameters which have been used in previous studies, like wound lateralization [12–14], or the injury severity score (ISS) [28]. A thorough and careful scoring of the ISS or of the abbreviated injury score (AIS) in such a context should be done in dedicated studies. Moreover, the exact height from which one may have fallen is difficult to estimate, or even impossible in some cases (e.g., falling downstairs), it was too rarely documented in our autopsy reports to be consistently considered for statistical analysis. Lateralization of injuries such as lacerations or fractures could also have been an interesting parameter to consider, as was done by Kremer et al. and Guyomarc'h et al. [13, 14], but in our opinion, and to the best of our knowledge, there is currently no convincing evidence of the role of lateralization in falls.

Conclusion

Autopsy findings may help to indicate the manner of death, but it must be kept in mind that either atypical homicide or atypical accidental cases can occur. If the forensic pathologist is confronted by trying to distinguish between two or three manners of death (homicide, accidental fall or sudden death with a fall), the simultaneous presence of blunt lacerations, deep bruises (both especially located in the cephalic region), and intracranial trauma, is strongly in favor of a homicidal death. The forensic pathologist must not be dogmatic in interpreting the significance of certain injuries based only on the statistical analyses when determining the manner of death. In cases requiring the distinction between homicidal and accidental fall injuries, the forensic pathologist must consider the police and death scene investigations to assist in the reconstruction of events.

Key points

1. The comparison of homicidal deaths from blunt trauma and non-homicidal deaths involving a fall from a low height showed that marked differences could be observed in the resultant wounds (e.g., more numerous and larger wounds occurred in homicidal deaths).
2. The so-called "HBL" rule, that has been previously proposed and is still discussed, was not found to be valid.
3. The simultaneous presence of at least one laceration, of one deep bruise, and of neuropathological injuries indicated strong presumption for homicidal deaths rather than non-homicidal deaths.
4. Although this study was primarily intended to give clues to the forensic pathologist to identify homicidal deaths, its results could also be of interest for physicians and surgeons working in emergency units who want to consider alternative mechanisms of injuries.

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