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PAPER
PATHOLOGY AND BIOLOGY

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Discrimination of Falls and Blows in Blunt Head Trauma: A Multi-Criteria Approach

ABSTRACT: In the discrimination of falls versus blows, the hat brim line (HBL) rule is mentioned in several textbooks as the most useful single criterion. Recent studies, however, have found that the HBL rule is only moderately valid and that its use on its own is not recommended. The purpose of this 6-year retrospective study was to find additional individually useful criteria in the distinction of falls from blows. Overall, the following criteria were found to point toward blows: more than three lacerations, 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 postcranial osseous and/or visceral trauma. Based on the most discriminating criteria, a decision tree was constructed to be potentially applicable to future cases.

KEYWORDS: forensic science, blunt head trauma, falls, homicide, skull fractures, lacerations

The distinction between accidental falls and homicidal blows is an important one in forensic pathology as it occurs frequently, but most importantly, because of the legal branching related to a homicide. Indeed, autopsy findings are often used to corroborate or complement investigative information.

In the discrimination of falls versus blows, the hat brim line (HBL) rule is mentioned in several textbooks as the most useful single criterion (1–3). According to this rule, an injury located at the level where the brim of a hat would lie is more likely the result of a fall, while a blow would generally produce a wound above this line. Recent studies, however, have found that the HBL rule is only moderately valid and that its use on its own is not recommended (4,5). The HBL rule should instead be used in conjunction with other tested criteria, such as the side lateralization and number of lacerations (5) and the length of lacerations (6). The purpose of this research is first to find additional individually useful criteria in the distinction of falls from blows, and second to construct a decision tree by selecting and combining criteria with the highest predictability rates.

Materials and Methods

This retrospective study used autopsy cases from the Montreal Laboratoire de sciences judiciaires et de médecine légale spanning a 6-year period (2000–2005). The selected cases represented falls downstairs, falls from one's own height, and homicidal blows to the head by a blunt weapon. Designation of cases as falls or blows was not solely based on head examination but on a thorough case review, including scene investigation, witness testimony, perpetrators confession, and other autopsy findings. The cases where a victim was struck while lying on the ground were excluded from the sample.

The same cases were previously studied by Kremer and Sauvageau for the following criteria: the number of lacerations, the location of lacerations and fractures in relation to the HBL, and the side lateralization of lacerations and fractures (5). In the present study, we further investigated other possible criteria: scalp laceration length; calvaria fracture type; number of facial abrasions, contusions, and lacerations (including mouth lesions); presence of lacerations on the ear; presence of facial fractures; pattern of postcranial osseous and visceral trauma; and the quantity of alcohol (mg/100 ml) when toxicology reports were available. The interobserver error was evaluated on ten cases by two of the authors and resulted in no significant discrepancies.

A total of 113 cases were studied: 29 cases of falls from one's own height, 21 cases of falls downstairs, and 63 cases of homicidal blows. Because of its controversial nature, one case was removed from the original sample. Cases of falls downstairs revealed a male: female ratio of 6:1 with an average age of 50 (±14.3 years ranging from 26 to 79 years), while the ratio for falls from one's own height was 8.7:1 with an average age of 51.5 (±17.5 years ranging from 15 to 85 years). Cases of blunt head trauma to the head showed a male:female ratio of 2.9:1 with an average age of 44 (±19.8 years ranging from 9 to 81 years). Toxicology reports (alcohol and drugs) were available for 95 cases (84.07% of the total sample).

The HBL definition used in this study is the one previously provided by Kremer et al. (4): 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

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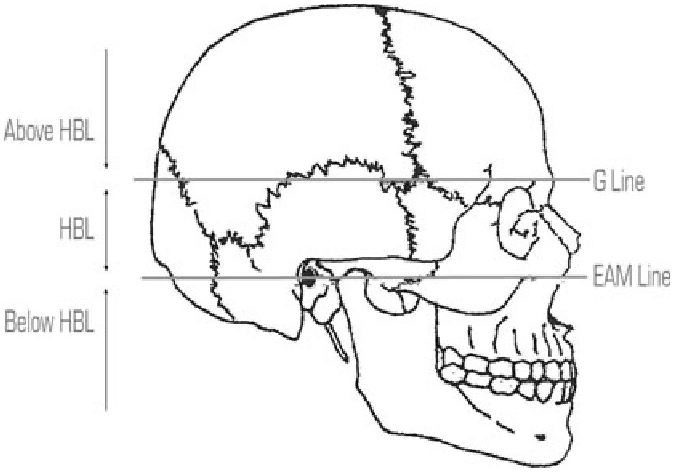

FIG. 1—*Schematic representation of the hat brim line, corresponding to the area located between the G-line and the EAM-line.*

TABLE 1—*Scalp laceration length in relation to circumstances of death.*

Circumstances	Average Length (cm ± cm)	Maximal Length* (cm ± cm)	Maximum Length† (cm)
Falls	1.26 ± 1.98	1.39 ± 2.22	7.7
Blows	3.86 ± 2.67	6.16 ± 4.22	13.8
Significance	$Z = -5.2$, $p = 0.00$	$Z = -6.03$, $p = 0.00$	—

*Average of the longest laceration per case.
†Longest laceration for all falls and blows.

TABLE 2—*Calvaria fracture type to evaluate circumstances of death.*

	Absence of Fracture	Fracture Type			
	Type 0	Type 1	Type 2	Type 3	Type 4
Circumstances	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Falls	12 (57.1)	23 (74.2)	11 (61.1)	4 (20)	0 (0)
Blows	9 (42.9)	8 (25.8)	7 (38.9)	16 (80)	23 (100)
Total	21 (100)	31 (100)	18 (100)	20 (100)	23 (100)
Significance	$\alpha = 0.00$, contingency coefficient = 0.50				

orbitale), the superior margin passing through the glabella (G-line), and the inferior margin passing through the center of the external auditory meatus (EAM-line) (Fig. 1).

For the purposes of this study as well, the face is defined as the region below the eyebrows comprised of the eyes, nose, mouth, and jaw with the ears and temples excluded. The scalp is defined as the region above the eyebrows, behind the ears, and above the neckline.

According to the physical force necessary to cause different types of calvarial fractures, these fractures were coded according to a scale from 1 to 4. In instances of different types of calvarial fractures in a single case, the highest score was kept. Calvarial fracture type 1 corresponds to linear fractures; type 2, radial fractures; type 3, comminuted fractures; and type 4, depressed fractures.

The moderate and more advanced decomposition cases were eliminated from the analysis of soft tissue facial trauma, postcranial visceral trauma, and alcohol quantitation because of the bias putrefaction artefacts introduce. As for postcranial osseous trauma, rib fractures were excluded from this study because of the difficulty in distinguishing rib fractures secondary to the trauma itself from rib fractures caused by resuscitation maneuvers.

The Statistica© Software 7.1 (Statsoft©, Tulsa, OK) was used to perform statistical analyses using cross-table analysis, nonparametric testing (*U*-test of Mann–Whitney), and a decision tree.

Results

The results regarding the number of lacerations, the location of lacerations and fractures in relation to the HBL, and the side lateralization of lacerations and fractures can be found in Kremer and Sauvageau (5), as well as the general data on gender and age. Although one case from the original sample was removed in this study, this difference does not cause any significant effect on the following analyses and interpretations.

Scalp Laceration Length (Average and Maximal Length)

Scalp lacerations were significantly longer in blows compared to falls (Table 1). Both the comparison of average length and maximal length of lacerations per case were significant. The distinction between falls from one's own height and falls downstairs, however, was not possible using these same criteria (average length $Z = -0.91$, $p = 0.36$; maximal length $Z = -1.04$, $p = 0.30$).

Calvaria Fracture Type

A significant difference between the type of fracture on the calvaria and the circumstances of death was found: falls presented mainly fractures of types 1 and 2 on our scale, whereas blows were more commonly associated with types 3 and 4 (Table 2). Pearson's chi-squared test did not reveal any statistical significance for the types of fractures between falls from one's own height and falls downstairs ($\alpha = 0.64$, contingency coefficient = 0.22).

Facial Abrasions, Contusions, and Lacerations

A *U*-test showed that facial abrasions could not be used as a statistically distinguishable criteria for blows versus falls ($Z = -0.5$, $p = 0.61$). On the other hand, another *U*-test revealed that facial contusions were significantly more common in cases of blows than in cases of falls ($Z = -4.01$, $p = 0.00$). In blows, the average number of contusions was 2.5 (±1.96), with a maximum of nine contusions per case, compared to an average of 1.1 (±1.48) and a maximum of seven per case for falls. As for facial lacerations, there were on average 2.48 lacerations (±3.69) per case in blows, with a maximum of 16, as opposed to an average of 0.42 lacerations (±0.99), with a maximum of four, for falls ($Z = -3.73$, $p = 0.00$). There was no significant difference between falls from one's own height and falls downstairs for abrasions ($Z = -0.57$ $p = 0.57$), contusions ($Z = 1.64$, $p = 0.1$), and lacerations ($Z = 1.02$, $p = 0.31$).

Ear Lacerations

Ear lacerations were evaluated separately from the rest of the scalp and face. Only nine cases presented ear lacerations, with eight of these cases related to blows. Despite this apparent predominance of ear lacerations in blows compared to falls, statistical evaluation was not performed because of the small number of cases.

TABLE 3—*Facial fractures in relation to circumstances of death.*

	Absence of Fracture	Presence of Fracture(s)
Circumstances	*n* (%)	*n* (%)
Falls	45 (57.7)	5 (14.3)
Blows	33 (42.3)	30 (85.7)
Total	78 (100)	35 (100)
Significance	α = 0.00, contingency coefficient = 0.37	

TABLE 4—*Postcranial osseous trauma in relation to circumstances of death.*

	Absence of Trauma	Presence of Trauma
Circumstances	*n* (%)	*n* (%)
Falls	44 (51.2)	6 (22.2)
Blows	42 (48.8)	21 (77.8)
Total	86 (100)	27 (100)
Significance	α = 0.01, contingency coefficient = 0.24	

Facial Fractures

The large majority of falls did not present facial fractures (90%). Facial fractures were more commonly encountered in blows compared to falls (Table 3). As with the other criteria so far, the difference between falls from one's own height and falls downstairs was statistically negligible (α = 0.39, contingency coefficient = 0.12).

Pattern of Postcranial Osseous (Excluding Ribs) and Visceral Trauma

The majority of falls (88%) and blows (66.7%) did not present postcranial osseous trauma. When present, however, postcranial osseous trauma were more commonly associated with blows than falls (α = 0.01, contingency coefficient = 0.24; Table 4). There was no difference in the incidence of postcranial osseous trauma between falls from one's own height and falls downstairs (α = 0.67, contingency coefficient = 0.06). The pattern of postcranial skeletal trauma in falls from one's own height was the following: one case of cervical vertebra fracture, one case of thoracic vertebra fracture, and one case of hyoid bone and clavicle fracture. In a somewhat different pattern, the three cases of falls downstairs were associated, respectively, with one ulna fracture, one wrist fracture, and one cervical vertebra fracture. As for the cases of blows, they displayed a greater variety of affected areas: fractures of the sternum, cervical vertebrae, thoracic vertebrae, hands, ulnae, radii, patellae, hyoid, and shoulder dislocation. It is interesting to note that within the superior limbs, eight cases were from the right side as opposed to only two from the left side.

As for postcranial visceral trauma, it was very rarely encountered in falls, with only a single case of lung contusion. In blows, postcranial visceral trauma were recorded in 12 cases out of 63 (α = 0.01, contingency coefficient = 0.26). These visceral trauma included lung contusions and lacerations, liver lacerations, pancreatic contusions, mesenteric contusions and lacerations, adrenal gland and kidney contusions as well as pericardium and subendocardial contusions.

Correlation of Criteria with Blood Alcohol Concentration

Overall, blood alcohol was more commonly present in falls victims (70%) than in blows victims (45%) (α = 0.01, contingency coefficient = 0.25). This high frequency of alcoholized victims was observed in both falls from one's own height and falls downstairs, with no significant difference between these two groups (α = 0.43, contingency coefficient = 0.12). Furthermore, average blood alcohol concentration was higher in falls compared to blows (104 mg/100 ml ± 102.3 in falls, 60.6 mg/100 ml ± 99.2 in blows, $Z = 2.28$, $p = 0.02$). Once again, the difference between falls from one's own height and falls downstairs was not statistically significant ($Z = -0.57$, $p = 0.57$).

It was then evaluated whether blood alcohol could be a factor explaining some misclassifications of circumstances of death using previously published criteria as well as the new ones proposed in this article. For example, it could be possible that a higher blood alcohol concentration would be found in cases where the HBL rule was not correctly predicting a fall case. To compare the misclassified and correctly classified cases in falls, four different baselines were used: presence or absence of alcohol and blood alcohol concentration below or above 40 mg/100 ml, 100 mg/100 ml, and 200 mg/100 ml. No significant correlations were observed.

Decision Tree

Four criteria were selected to build a decision tree. To improve statistical results and avoid sample bias as much as possible, only the criteria applicable to all cases were used. Combinations of the statistically significant criteria were then tested by running a decision tree analysis with Statistica©. It allowed for a classification of the criteria using a discriminating method by univariate divisions and assigned each criteria a weight factor (WF) scaled from 0 to 100. Moreover, some of the criteria resulted in a similar classification of cases; in these cases, the one with the smallest WF was excluded. The four parameters kept were the number of scalp lacerations (WF = 41), the scalp laceration length (WF = 100), the vault fracture type (WF = 79), and the presence or absence of facial fractures (WF = 79). For each branch, the numbers of falls and blows cases are indicated as well as the sample number at each node of the tree (Fig. 2). Given that four cases of blows and nine cases of falls were misclassified, the positive predictive value reaches 86.76% and the negative predictive value is 91.11%.

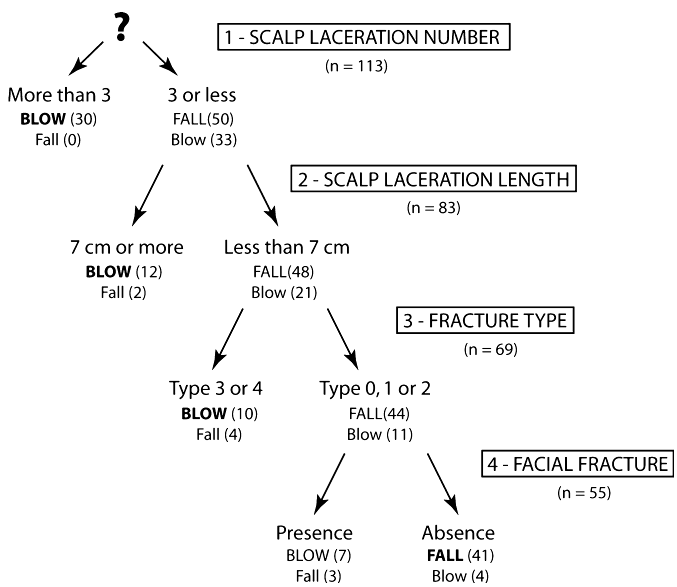

FIG. 2—*Decision tree in the discrimination of falls from blows.*

Discussion

The discrimination of falls from blows is a common but challenging problem for the forensic pathologist. Although the HBL rule has historically been used frequently to aid in this differentiation, it is with Ehrlich and Maxeiner that a systematic study of the rule began (6). The latter studied the localization of scalp lacerations in relation to the HBL, as well as the length and number of scalp lacerations (6). Afterward, additional research was performed to further evaluate the validity of the HBL rule and to establish additional criteria. Kremer et al. (4) studied the localization of skull fractures in relation to the HBL, the side lateralization of skull fractures, and the number of scalp lacerations. In a following article, Kremer and Sauvageau (5) compared the validity of the HBL rule and the side lateralization of scalp lacerations and skull fractures. Scalp and skull lacerations located below the HBL were also evaluated in relation to the circumstances of death (7). Finally, in an effort to make the discrimination between falls and blows more accurate, a combined criteria tool was proposed, with a better distinction rate than individual criteria (6). Despite all this research progress, there is a lot more work to be performed before forensic pathologists can easily and accurately distinguish falls from blows in each individual case of their daily practice.

Summary of Previously Proposed Criteria

Both scalp lacerations and skull fractures located above the HBL are more likely to result from blows than falls (4–7). In wounds located inside the HBL, lacerations are more prone to be related to falls whereas skull fractures are related to falls or blows in relatively similar proportions (5). It should be emphasized, however, that the HBL rule is far from being a perfect criterion, and to rely solely on this rule to distinguish falls from blows in a specific case would be a severe mistake (4–7).

Side lateralization of fractures and lacerations was also proposed as a useful criterion: wounds on the right side of the head are generally indicative of a fall whereas those on the left side suggest a blow (4,5). As for the numbers of scalp lacerations, more than three or four lacerations strongly suggest blows while, for a smaller number of lacerations, it is the opposite (4–6). Once again, though, none of these criteria are perfect.

The length of scalp lacerations, as previously investigated by Ehrlich and Maxeiner (6), was found to be longer in blows than in falls. More precisely, it was proposed that a scalp laceration of more than 6 cm was indicative of a blow because lacerations in falls rarely exceeded 6 cm (6). The results of the present study confirm that lacerations are longer in blows compared to falls. In our studied population, though, 7 cm seems a better cutoff length. The observation that lacerations are generally longer in blows than falls could be explained by usually a stronger force of impact involved in the former. It is likely, however, that other factors may come into play as well, such as the type, weight, and length of the weapon or angle and location of impact.

Newly Studied Criteria

In the present study, several possible new criteria were studied: calvaria fracture type, facial cutaneous lesions (abrasions, contusions, and lacerations), ear lacerations, facial fractures, and patterns of postcranial osseous and visceral trauma.

A scale of calvaria fracture type was proposed here, according to the physical force necessary to cause these fractures. Linear (type 1) and radial fractures (type 2) were more likely to result from falls, whereas comminuted (type 3) and depressed (type 4) fractures were strongly in favor of blows. This unequal distribution of falls and blows in relation to this scale of calvarial fractures is easily explained by the fact that blows generally involve stronger forces of impact, which in turn translate to fractures of a higher level on our scale.

As far as we know, facial cutaneous injuries were never evaluated in the context of discriminating falls from blows. According to the results of the present study, facial abrasions were not very useful to orient toward one circumstance of death or the other, but facial contusions and lacerations could be exploited. In fact, a higher number of facial contusions and lacerations were in favor of blows. Similarly, the presence of facial fractures also revealed to be a useful criterion pointing toward blows.

Ear lacerations deserve a separate discussion because they seem to behave differently from scalp and facial lacerations. Out of the nine cases with ear lacerations, eight cases were related to blows. This may seem surprising considering that technically, ears are located inside the HBL and, therefore, ear lacerations should be encountered more often in falls. Considering the anatomical location of the ears as well as the physical action of falling, however, this may be explainable: it is less likely for a falling person's ears to experience the primary impact as opposed to a person receiving blows to the head. When a person falls on their side, their shoulders hit the surface first followed by their parietal eminences. If a person falls backwards, their occipital hits first, and if a person falls frontward, their frontal hits first. The ears are thus not likely to be injured in a fall, regardless of the direction of fall.

When confronted with blunt head trauma, forensic pathologists know not to look solely at the head trauma but to consider all autopsy findings to assist themselves in the challenging distinction of falls from blows. Indeed, in the few cases presenting postcranial trauma, both osseous and visceral, the presence of such trauma will be an argument toward blows. The absence of such finding should be weighed, however, against the fact that postcranial traumas are extremely uncommon in most cases of fatal blunt head trauma by falls or blows. Therefore, to look at the rest of these autopsy findings will seldom be useful. This is in keeping with previous studies that have also shown that in fatal falls, an isolated head trauma is by far the most common type of injury (8–13).

Several studies have reported that alcohol is a significant contributing factor in most falls (12–14). Alcohol is a depressant of the central nervous system, and this translates itself to a loss of coordination and a difficulty to process new information (14). These effects in turn can lead to a fall or aggravate it. Not only did the present study confirm that alcohol is implicated in most fatal falls, but also it demonstrated that the presence of alcohol is more commonly encountered in falls than in blows. Furthermore, blood alcohol concentration is significantly higher in falls than in blows. Although not pathologic criteria *per se*, the presence and quantity of alcohol proved to be statistically distinguishing criteria for the circumstances of death. It should be noted that the presence of other drugs or medication may also play a role, but it was not studied here.

Although alcohol presence and quantity correlate with the circumstances of death, it does not seem to bias any of the other investigated criteria. This is in line with findings from a study of ground-level falls, which found that there was no difference in the severity of injuries regardless of the presence or absence of alcohol (13).

Falls from One's Own Height Versus Falls Downstairs

For all the previously proposed criteria (4,5) as well as the newly studied ones, none were useful in the distinction between falls from one's own height and falls downstairs. The reason for this may be that, contrary to popular belief, these types of falls are physically quite similar. When a person falls downstairs, it is as if they are falling from their own height, then falling only by small distances equivalent to the height of a step. In other words, both types of falls involve falling from a low height, even if the distance between the top and bottom of a staircase can be long. The discrimination between these two circumstances of death is not necessarily relevant because the scene investigation generally suffices to clarify the situation. The problem, however, is to establish if the victim simply fell or was hit.

Combined Criteria Tool and Decision Tree

The combined criteria tool in Kremer and Sauvageau (5) was established using two or three of the following criteria: the localization of skull fractures in relation to the HBL, side lateralization of skull fractures, and number of lacerations. Blows were classified correctly in 100% of cases when using either two or three criteria. Falls had a more variable predictability rate that ranged between 62.5% and 83.3% depending on the number and nature of the combined criteria. This tool is of limited used, however, because it cannot be applied on several cases. For example, not all cases present skull fractures and, even in cases with skull fractures, a right-side or left-side lateralization is not always present.

The decision tree classified 82% of falls and 93.7% of blows correctly. Because only criteria applicable to all cases were used in the construction of the tree, the decision tree integrates all of the 113 cases in our population and could be used on all future cases. The decision tree thus shows the strong discrimination potential between falls and blows case patterns. Perfect discrimination remains unrealistic. Nevertheless, in addition to crime scene elements and other autopsy findings, this type of tool can be more than informative.

Conclusion

The aim of this study was to improve the discrimination between falls and homicidal blows by a blunt weapon in a forensic pathology setting. The request to give an expert opinion on this distinction is a common and crucial one given the legal consequences.

Overall, based on the present study as well as previous ones, the criteria pointing toward blows are:

- More than three lacerations.
- Laceration length of 7 cm or more.
- Comminuted or depressed calvarial fractures.
- Lacerations or fractures located above the HBL.
- A left-side lateralization of lacerations or fractures.
- More than four facial contusions or lacerations.
- Presence of ear lacerations.
- Presence of facial fractures.
- Presence of postcranial osseous and/or visceral trauma.

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