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Original article

FORENSIC ANALYSIS OF BLOOD STAINS AND THEIR SIGNIFICANCE AS EVIDENCE

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Abstract

Criminological operational analyses of blood stains obtained at the crime scene are of great importance in determining the identity of the person who has committed a criminal offence.

The aim of this study was to illustrate the significance of evidence of blood stains and their appropriate interpretation in solving criminal offences, mainly in the area of homicides.

We made an experiment using pork blood, a metal bar to make enough hits, a doll's head, soaked gauze in pork blood which imitated the head tissue, a calliper to measure the dimension of blowed up blood drops and overalls with protective equipment.

The subject of the analysis were the spatters of blood traces got with just one strike, and were projected on the vertical surface of the wall next to the body, which could be divided into three groups or clusters. From each group of blood pattern projected on the vertical surface, ten (stains) spatters were analyzed, which could be a representative sample for the group of stains from which they originated.

Keywords: blood, blood stains, homicides

Introduction

The complexity of homicides, which are becoming more frequent not only in the Republic of North Macedonia but also worldwide, and the problems the experts face while working on solving such cases (criminal offences) was the main motive for this study which analyzed blood stains and the significance of their interpretation[1-3].

Appropriate handling of blood stains and their expert analysis can provide answers to many questions what exactly happened and about the order of events occurring during the crime[4]. A large number of criminal offence - homicide or attempted homicide is left unsolved due to lack of evidence or insufficient comprehension and interpretation of evidence[5].

Parallel to the improvement of techniques, instruments and methods for solving homicides, there is an improvement of the methods and techniques for professional commission of criminal offenses where the perpetrator leaves less and less traces behind him or successfully conceals them by making it difficult for forensic experts to identify them[6-8].

The approach to blood pattern analysis (BPA) must adhere to the scientific methods and rely on the principles of medicine, criminology, physics and mathematics[9-11]. Education in these areas is highly recommended. A combination of training through formal education and experience is necessary before an individual acquires adequate proficiency in the analysis of bloodstain pattern[12-15].

The dynamics of the occurrence of blood traces is a complex system of variables that are interconnected and directly conditioned by the force of the impact, the speed of the impact and the place where the concentrated physical or other type of force acts[16-18]. Therefore, it is very important to analyze the trace itself, its appearance, the way it was created, its correlation with other evidence and the consequence of the crime[19-20]. Based on the traces of blood, the position of the victim can be proved, possibly manipulating the victim's body (for example, the victim was killed in one place and the body was moved to another)[21-23]. In this context, the perpetrator of the crime and the tool by which that crime was committed can also be discovered.

Material and methods

We made an experiment using pork blood, a metal bar, doll's head, soaked gauze in pork blood which imitated the head tissue, overalls with protective equipment and a calliper to measure the dimension of blowed up blood drops.

Using a metal bar, a hit on the head at the left parietal bone had been made. Above the head a soaked gauze in pork blood was placed which imitated the head tissue. If real, the wound caused in this way, would have the characteristics of contusion. The person who would have inflicted the blow with a bluntly hard object is dressed in white overalls on which we could easily notice the possible blood stains caused by the blow.

Results

After the hit the spatters were detected:

- on the vertical surface (wall) located normal relative to the body
- on the horizontal surface near the doll's head
- on the doll's clothes, and
- on the clothes of the person who inflicted the blow.

The subject of the analysis were the spatters of blood trace that were made with just one strike, and were projected on the vertical surface of the wall next to the body, which could be divided into three groups or clusters as indicated by arrows in Figure 1.

From each group of blood patterns projected on the vertical surface, ten (stains) spatters were analyzed, which should be a representative sample for the group of stains from which they originated. The trigonometric analysis of blood stains was done by first withdrawing symmetrically from the middle of the stains in order to obtain the so-called point of convergence. Then, the impact angles of each of the stains were calculated respectively, i.e., the angle at which they were projected on the vertical surface, and then a standard deviation from the total number of impact angles was calculated in order to see how much the angles deviated from their mean value.

The value of the angle was calculated by measuring the length and width of the analyzed spatters, and then calculating the quotient of the width and length. The width and length of the blood stain was a sinusoidal function from the impact angle. The impact angle was calculated according to the following formula:

$$sin = \frac{\text{width of spatter}}{\text{length of spatter}}$$

$$arcsin = \text{impact angle}$$

The first group of analyzed spatters, shown in Table 1, had a significantly greater length than width, and consequently had an elliptical elongated shape with tails that showed their direction of movement and an impact angle of less than 90°. If the symmetries are pulled through the middle of the spatter and continue in the ring opposite their direction, they will merge into an area called the convergence point.

Table 1. Display of the length, width and impact angle of the first group of analyzed spatters

SPATTER	LENGTH (mm)	WIDTH (mm)	IMPACT ANLE (°)
1	6.0	2.4	23.57
2	8.3	2.7	18.98
3	8.0	3.2	23.57
4	11.1	3.9	20.56
5	12.8	4.5	20.58
6	6.3	2.2	20.43
7	3.2	1.5	27.95
8	7.6	3.3	25.73
9	14.4	4.4	17.79
10	3.4	2.0	36.03

The second group of spatters, shown in Table 2, as well as the previous group of analyzed spatter, also had an elliptical shape with tails and an impact angle of less than 90°. The path of movement of the spatters was parabolic. They produced secondary spatters that fell on a horizontal surface of small size and circular shape. If the symmetries are withdrawn from these spatters and continue in the opposite direction of movement, a common area in which they intersect will also be obtained.

Table 2. Display of parameters of the second group of analyzed spatters

SPATTER	LENGTH (mm)	WIDTH (mm)	IMPACT ANLE (°)
1´	17.8	5.6	18.06
2´	12.1	4.0	19.27
3´	14.0	4.9	20.49
4´	8.1	3.4	24.83
5´	9.4	4.4	27.91
6´	10.7	4.4	24.28
7´	14.0	7.4	31.91
8´	10.1	5.7	34.36
9´	11.2	6.2	33.61
10´	6.8	2.0	39.22

In the third group of analyzed spatters, shown in Table 3, the same characteristics appeared as in the previous two. The spatters were longer than the width and had an elliptical shape with a tail and an impact angle of 90°. If symmetries are drawn through them, they will also merge into one area.

Table 3. Display of parameters of the third group of analyzed spatters

SPATTER	LENGTH (mm)	WIDTH (mm)	IMPACT ANLE (°)
1´´	9.8	3.2	19.06
2´´	17.3	5.5	18.53
3´´	8.1	3.2	23.27
4´´	14.4	5.1	20.74
5´´	10.2	4.5	26.18
6´´	11.1	5.2	27.93
7´´	7.2	3.7	30.92
8´´	10.7	6.3	36.07
9´´	14.3	7.8	33.06
10´´	8.0	4.2	31.67

Table 4. Joint display of the impact angles of the scattered drops from all three groups of analyzed blood spatters

IMPACT ANGLES 1 (°)	IMPACT ANGLES 2 (°)	IMPACT ANGLES 3 (°)
36.03	34.36	36.07
27.95	33.61	33.06
25.73	31.91	31.67
23.57	27.91	30.92
23.57	24.83	27.93
20.58	24.28	26.18
20.56	20.49	23.27
20.43	19.27	20.74
18.98	18.06	19.06
17.79	16.85	18.53

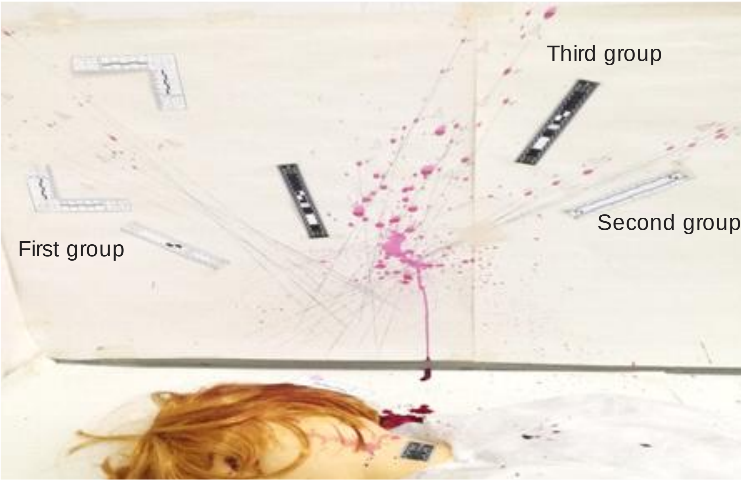

Fig. 1. Three groups of spatters

If we analyze the relation between the impact angles of the first, second and third group of spatters from the analyzed traces shown in Table 4, we will notice that their value decreases proportionally to 17.79, 16.85 and 18.53 degrees, respectively. This is best illustrated in Figure 1, where among other things it can be concluded that if the angle is sharper (smaller), then the blood stains are farther from the source, i.e., the point of convergence and *vice versa*.

The proportionality of the dispersing can be proved by the calculation of the standard deviation of the values of the widths and lengths, which indicated that all the elements in the group of data were very close to the average value and were gravitating around this value, hence, they originated from the same source (Table 5). Although the difference between the values of all three groups of spatters in all of them was get identical standard deviation (Table 6).

Table 5. Joint display of the width and the length of blood drops from the three analyzed groups of spatters

Quotient of the width and length 1	Quotient of the width and length 2	Quotient of the width and length 3
0.59	0.56	0.59
0.47	0.55	0.55
0.43	0.53	0.53
0.40	0.41	0.51
0.40	0.42	0.47
0.35	0.41	0.44
0.35	0.35	0.40
0.35	0.33	0.35
0.33	0.31	0.33
0.31	0.29	0.32

Table 6. Arithmetic mean and standard deviation to the quotients of the width and length of the scattered drops

	Quotient of the width and length 1	Quotient of the width and length 2	Quotient of the width and length 3
Arithmetic mean	0.40	0.42	0.45
Standard deviation	0.08	0.09	0.08

It could be noticed that the drops which dispersed higher had much severe impact angle in the three groups of blood patterns. The angles values in the tables are sorted from larger to smaller, which indicates the order of dispersion of the blood drops on the vertical surface.

The fourth group of analyzed blood spatters on the vertical surface were projected at an angle of 90° with respect to the blood source. Circular spatters were spotted with very small dimensions and had a mist-like effect. These types of spatters at the crime scene are usually at the same height as the source, i.e., the place where the impact is placed, especially if the body was in a standing position, then fell to the floor and the perpetrator continued to strike.

Except these blood stains which were projected on the vertical surface, we could see the flowing stains on the victim. The flowing stains are a result of the gravity and in this experiment this type of stains occurred at the side parts of the face and neck.

During the experiment, another type of stains was obtained, which were projected on the perpetrator’s clothes (Figure 2). They were grouped in four groups depending on place where they were projected. All of them had very small dimensions and number.

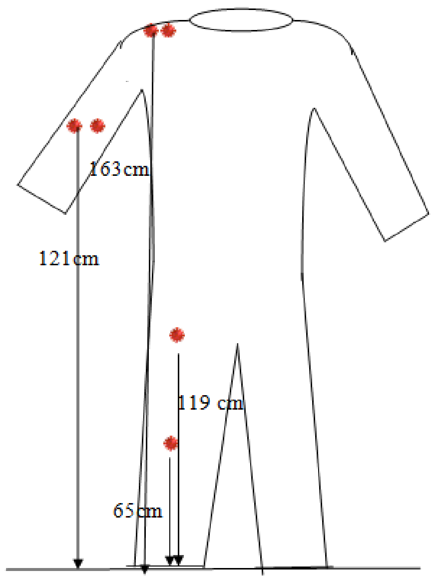

Fig. 2. Scheme of the stains on the clothes of the executor

Discussion

When a crime results in bloodshed, the blood left behind functions as evidence for investigators. However, a bloodstain pattern analyst can't simply glance at drips and smears of blood and immediately tell you the who, what and when of a crime scene. Blood spatter analysis takes time and provides only a few pieces of the total crime puzzle. Blood spatters can guide the recreation of a crime thanks to the same laws of motion, gravity, physics and chemistry that govern all liquids. Blood travels in spherical drops because of surface tension, the tendency of liquids to minimize surface area because their molecules are attracted to one another. In other words, it's cohesive[24]. Also, its drops behave in predictable ways when they strike a surface or when a force acts on them. In general, more liquid - or a fall from a greater height - will make a larger puddle. Moreover, droplets striking a hard surface will retain a more circular shape than those landing on a softer surface like carpet, which can partially absorb the liquid and cause the edges to spread[25, 26]. These are just some of the many factors a blood spatter analyst must consider.

One pattern of slow-moving blood, called "drips," occurs after an injury, and has a relatively large footprint of 0.16 inches (4 millimeters) or more. Drips which result from blood dripping onto blood, can fall from a bleeding nose or wound, or a motionless, bloodied weapon or object. A moving object produces what's known as a cast-off pattern. Other low-velocity patterns include blood pooling around a victim's body and impressions left by bloody objects. This latter phenomenon, called a transfer, sometimes retains the shape of the object that made it[26].

At the other end of the scale are the tiny droplets caused by blood traveling at high speeds. These are usually caused by gunshot wounds, but they can also result from explosions, power tools or high-speed machinery. These fast-moving drops leave stains measuring less than 0.04 inches (1 millimeter) across.

Between these extremes lies a range of medium-sized droplets. Typically measuring 0.04 to 0.16 inches (1 to 4 millimeters), they can be caused by a blunt object such as a bat or a fist, or can result from stabbing, cast-offs or even bloody coughs[26].

Drop size is only one aspect used in analyzing blood spatters.

To analyze a bloodstain pattern, an expert relies on three main interrelated elements: the size, shape and distribution of bloodstains. Blood drops that fall straight down, with little but gravity and air resistance affecting them, make round stains. Blood moving at an angle and sped along by some force, however, tends to make elongated marks, especially when it strikes a nonporous surface.

As a rule, following the long axis of the stain from the blunter end to the sharper, more disturbed edge reveals the direction the blood traveled. If a number of stains radiate outward, analysts can draw lines backward along these axes to an area of convergence. But this gives them an area in only two dimensions. Investigators must also determine the blood's impact angle[24].

The lower the angle at which blood strikes a surface, the thinner and more elongated the stain. The converse holds true as well. Measuring a stain's width and length, analysts use the Angle of impact = arcsin (stain width/stain length). The greater the difference between the width and length, the sharper the angle of impact[24].

Increasingly, analysts are taking advantage of computer programs that allow them to store spatter data, calculate values such as impact angle, and display information in helpful 3D renderings. Developers are working on software that can automatically reconstruct a single coordinate frame from several images, limiting user input. Others are working on using laser scanning and even machine learning to analyze the blood spatter.

Conclusion

In conclusion, the results obtained during the experiment showed that by applying one strike several groups of spatters are obtained, which at first glance give the impression that multiple blows have been applied. When analyzing the resulting spatters, it was concluded that the spatters were designed on the vertical surface.

The spatters that had an impact angle of less than 90° were elliptical in shape, and those that had an impact angle of 90° were circular in shape, with very small dimensions and gave a misting effect. The symmetries of all spatters converged to one area in the space where they intersected showing the source of the bleeding, i.e., the site of injury. Hence, the position of the deceased and the source of the bleeding and possible manipulation of the corpse can be determined. We concluded that the dispersion of blood droplets did not depend on how much blood the drop contained, but on the amount of width and length of the drop and its impact angle.

On the horizontal surface, spatters were designed, which were obtained from the three groups of spatters on the vertical surface, which due to their short parabolic path in the form of drops were projected on the horizontal surface near the blood source. Traces of blood in the form of a flowing stains were also visible on the horizontal surface, which due to the large amount of spilled blood formed a saturation stain next to the victim. Traces of flowing stains could also be seen on the sides of the victim's face and neck.

From the traces of blood projected on the clothes of the perpetrator, one can assume the height of the perpetrator and whether he/she was right-handed or left-handed.

We can conclude that it is important to know the appearance of the traces of blood as well as the characteristics of mechanical injuries.

Conflict of interest statement. None declared.

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