 FORENSIC SCI SEM

Received 10 March 2012
Received in revised form 2 May 2012
Accepted 21 July 2012
Available online 1 January 2013

Peer Reviewed 2157118X.3.R1

Morphological Characteristics of Bloodstains - Forensic Consequences

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Abstract Bloodstains are almost always present at the scene of a violent act and often can bring invaluable data regarding the cause of death, weapon, perpetrator, the kinetics of the traumatic event, etc. However, often important information which can be brought by the bloodstains is missed due to incorrect sampling and analysis of this material evidence. The purpose of this presentation is to summarize the main morphological characteristics of the bloodstains and to present the positive outcomes resulted from a correct identification.

Keywords: Forensic science; Physical evidence; Morphological characteristics; Bloodstain analysis; Spatter.

Introduction

Blood is a bodily fluid present in all animals, which has as a main function the delivery of nutrients and oxygen to all tissues and the transport of catabolites to specific organs of excretion (respiratory system for carbon dioxide, renal system for protein degradation products, etc.) [1].

In humans (as in almost all vertebrates) the blood is a reddish fluid, due to the presence of hemoglobin, a complex structure containing iron and proteins. Blood is circulated in the body throughout vessels (arterial and venous) and the active force is represented mainly by contractions of the heart.

Blood is a form of physical evidence, often analyzed in forensic sciences as it can bring useful information in the following areas:

- Origin of bloodstains (arterial, venous, pulmonary, digestive, etc.)
- Type of impact (gunshot, fall, aggression)
- Direction of impact (e.g. backspatter, forward spatter) [2]
- Mechanism of spatter pattern production [2]
- Characteristics of the weapon [2]
- Position of the victim and aggressor [2]
- Postmortem interval [3]
- Identification of the victim/aggressor, etc.

In order to respond to most of the objectives presented above, we must analyze two main characteristics of the bloodstains: (1) the morphological characteristics of the blood stain and (2) identification data, obtained through specific serological, immunological, and genetic tests, which can aid us, with a variable degree of certainty, in telling to which person the analyzed blood belongs to.

The purpose of this article is to summarize the main morphological characteristics of the bloodstains and their consequences in forensic practice.

Color

The blood color is variable depending on its source. Arterial blood is present in the lungs, left chambers of the heart and arteries (except for pulmonary arteries) and has bright red color [4].

Venous blood is present in the right chambers of the heart, veins (except for pulmonary veins), and pulmonary arteries, and has a dark-red color.

Postmortem blood is also dark-red, as the color is determined mainly by the oxygenation of the hemoglobin. After death the oxyhemoglobin transfers the oxygen to the surrounding cells, accepts carbon dioxide and resembles venous blood, irrespective of the da facto source or location [5].

After death the blood remains bright red in cases in which the tissues cannot accept the oxygen. For example in carbon monoxide or cyanide poisoning, or in refrigeration the cellular respiratory chain is blocked and therefore the cells cannot utilize the oxygen brought to them by the blood.

This in turn leads to the appearance of typical, bright red lividities in these cases, which significantly aids the legal medical physician in diagnosing the cause of death.

In methemoglobin poisoning the blood is blue-brownish and this can also be useful in detecting a possible intoxication with nitrites, nitrates, or other methemoglobin causing substances.

The blood which has had a passage through the upper respiratory system has a frothy appearance, due to the bubbling effect of the air present at this level.

The blood from the digestive apparatus has a typical tar appearance, due to the effect of the hydrochloric acid on the hemoglobin.

Aggregation state

Most blood stains are solid, as

(1) they typically contain only small quantities and (2) the water component tend to evaporate quickly. Medium or large sized blood stains can be either solid or liquid, depending mainly upon (1) the time passed from the moment of its production until its analysis, (2) absorbent capacities of the surface (time until complete evaporation is inversely correlated with the absorbent capacity of the surface), (3) temperature (time until complete evaporation is correlated with ambient temperature [1, 6].

Patterns of bloodstains

According to James and Kish, bloodstains can be classified in:

- passive patterns, produced by transfer, drop, flow, or large volumes
- active patterns, produced by impact mechanism, secondary mechanism or projection mechanism, and
- altered patterns, caused by clotting, dilution, diffusion, insects, sequences and voids.

Passive patterns

Free-falling patterns – appear when the blood droplets are falling under the gravitational force and are not broken into smaller droplets during their descent. The shape of these free falling droplets depends upon:

- The angle of the surface upon which they fall. If the surface is horizontal the bloodstain in round; if there is an angle between the surface and the horizontal line, the bloodstain becomes elongated, and the elongation is directly correlated with the magnitude of this angle. (see Figure 1)
- The volume of blood – if the volume of blood is large enough, the contact with the surface can lead to the appearance of secondary droplets (like the rays around the sun)
- The falling distance – if the falling distance is long enough the contact with the surface can lead to the appearance of secondary droplets (like the rays around the sun).

Drip patterns. Appear when multiple free-falling droplets fall on a surface on after the other, in the same spot. They are typically larger than a free falling pattern, irregular, with satellite spatters

Drip trails. Appear when the blood droplets fall during o horizontal move of the source; therefore in their production are involved two forces – a horizontal one, caused by the moving of the source and a vertical one (gravity). Subsequently the blood stains are elongated, and the elongation is directly proportionate with the speed of the source.[8] If the speed is slow the spots forming the bloodstain are almost circular; if the speed is higher the spots are elongated and the smoother end suggests the direction of walking.

Flow patterns appear when a volume of blood is slowly displaced from its initial position, by flowing on the surface until it reaches the final position. (see Figure 2).

They have significant medical-legal consequences as their pattern may suggest that the body was moved/the person has moved from the initial position before death [9].

Active patterns

Active patterns can be classified in spatters (resulting when the blood spreading is caused by a force applied to the source of blood) and splashes (splash patterns, resulting when a large amount of blood comes in contact with an even surface at minor or low velocity [10]) .

Spatters can be classified according to the mechanism of production and to the velocity. According to the velocity, spatters can be:

- Low velocity spatters (less than 1.5 m/sec) – they are large (more than four millimeters, irregular, sometimes with centrally pointed or elongated secondary stains. A typical example is a bleeding from a ruptured varicose vein.

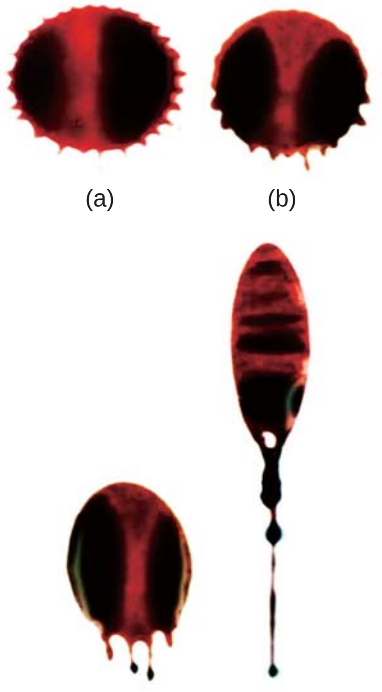

Fig. 1 Free falling patterns after non-perpendicular impact from 0.8 meters (a – at an angle of 80 degress, b – at an angle of 60 degrees, c – at an angle of 40 degrees, d – at an angle of 20 degrees. After Adam, with permission [7].

Fig. 2 Flow pattern – at the mobilization of the body, if the blood is not clotted/dried, it moves from the initial position to a new position of equilibrium, leaving a trail between the initial and the final position.

Fig. 3 Impact spatter. The bloodstains identifiable on the left arm have resulted from the impact of the head with a hard surface (secondary to a fall).

- Medium velocity spatters (1.5 – 7.5 m/sec) – they are smaller (1-4 mm), with an irregular shape and sometimes larger volumes. A typical example is somebody being beaten with a solid object.
- High velocity spatters (described at velocities over 35 m/sec) are small (less than 1 mm in diameter). Usually associated with gunshot injuries [10].

According to the mechanism of production, spatters can be spatters associated with a secondary mechanism, impact spatters, and spatters associated with a projection mechanism.

Spatters associated with a secondary mechanism. Spatters appear when in the final pattern of the bloodstain is involved a secondary mechanism, and is dependent upon:

- the source of the bleeding (arterial, venous, digestive, etc)
- the flight pattern of the spatter before reaching the target surface
- the angle of impact
- Texture of the target surface.

Impact spatter results when an object directly strikes a source of exposed blood; this is the most common type of spatter analyzed in forensic medicine as its analysis can bring a lot of useful data. It can be further classified in:

- impact spatter associated with blunt or sharp force trauma (see Figure 3). The quantity of blood, and subsequently the spatter analysis is highly dependent upon the force of the traumatic event, but also upon the hit area (larger spatter in areas with thin skin or with arteries lying immediately underneath the skin (like the cervical area)
- impact spatter associated with gunshot wounds, with two subtypes – back spatter and forward spatter. Forward spatter appears when the bullet exits the body, and is caused by the blood entrained by the either the bullet or small solid tissues mobilized by the bullet when passing through the body. Backspatter appears when the bullet enters the body, and is caused by the rapid expansion of a gas in a limited space, leading to a high pressure at the skin-air interface, and subsequently to ruptures with small droplets of blood emerging in a anterograde direction. Back spatter can be used to differentiate a suicide from a homicide, or to detect the aggressor.

Spatter associated with a projection mechanism are defined as a "projected bloodstain… created as the results of a force other than impact [2]", and can be further sub-classified in:

- Arterial mechanisms – the projection force is the arterial pressure leading to a typical beans on a string appearance (during systole the pressure is higher and subsequently the blood stain is higher whilst during diastole the pressure is lower, leading to a smaller trail). The pattern depends upon the location of the artery (greater spots from superficial arteries and smaller one from deeper ones), volume of blood, orientation of the surface (due to the higher volume of an arterial bleeding, if the surface is not horizontal from the initial spot/spots will appear secondary flow patterns), nature of the surface, blocking effects of the muscles (if the arterial rupture is within or under a muscle layer), bloking effects of the clothes (dependent upon the thickness and material), position of the victim, movements of the victim (both passive and active), occuring after the arterial rupture, *etc*.
- Venous mechanisms – the projection force is much lower than the one present in the arterial mechanism, but can produce a significant, even lethal blood-loss.
- Expiratory mechanisms appear when the projection force is represented by the air, which propels a mixted combination, of blood and air. It appears in many circumstances, both violent and non-violent like the rupture of a Rassmussen aneurism, blood exhalation, spitting of blood, *etc*.[11]
- Cast-off mechanisms appear then the blood is taken on the surface of the object with which the trauma has occurred, and then leaves the object during its movement, due to centrifugal forces.

Splashed bloodstains. Usually appear when the droplets have more than 1 ml in volum, and are characterized by a rounded

Table 1. Algorithm for distinguishing entomological artifacts from human bloodstains [15]

Documentation of entomological evidence at the scene	present at the scene as long as they have nutrients or when trapped any flies must be analyzed, documented and identified, including dead flies identification of insects at the scene makes mandatory the search for entomological artifacts
Documentation of the range of stains	insect activity is higher near light sources, and light colored areas. These must be checked even if at a distance from the corpse.
Comparison with known fly artifact patterns	- may be useful in documenting the type of insect present at one time at the scene
Identification of suspected human bloodstain patterns, by removing patterns specific to insect activity	The following must be removed: • stains with a tail/body ratio >1 • stains with tadpole or sperm type structure • stains with a sperm cell type structure not ending in a small dot • stains without a distinguishable tail and body • wavy or irregular stains • stains whose direction does not correspond with the normal convergence point

central area with secondary rays and splashes, which tend to exhibit reverse directionality.

Altered patterns

Blood aging. During the aging process of a bloodstain the hemoglobin suffers oxidative processes, causing a shift in color from red to brow, green, dark brown and black. All morphological tests can only give a very rough estimate regarding the age of the stain. Better results are obtained by using simultaneously multiple advanced laboratory techniques like UV spectrometry of the plasma or atomic force microscopy of the red cells.[12]

Blood drying. Is dependent upon the initial volume, the surface, temperature and humidity. Blood drying starts at the edge of the stain (the thickness is minimal) and progresses toward the center. For details see the study conducted by Ramsthaler *et al* [13].

Blood clotting. Clotting normally appears after 7-15 minutes of time after the blood is exposed, but the time is highly variable, depending upon various preexistent pathologies (blood clotting disorders), medication (for example aspirin increased the time), or other local factors (the surface, concomitant presence of corticospital fluid, etc. Treatment with anticoagulants does not seem alter significantly the extracorporeal blood clotting time [13]. According to James[2] in forensics the main uses of clotted bloodstains are: (1) the presence of a significantly dried and clotted blood suggest the passing of a significant time from the traumatic event, (2) clotted bloodstains on the victim's clothes or surrounding areas suggest, in case of a heteroaggression, the presence of a significant interval between the blows (needed for enough blood to emerge and coagulate), (3) clotted bloodstains associated with a pedestrian traffic accidents suggest and multiple impacts with multiple vehicles and a free interval in between and (4) couching or exhaling clotted blood suggests that between the aggression and death a significant interval of time has passed (the blows did not cause the death immediately)

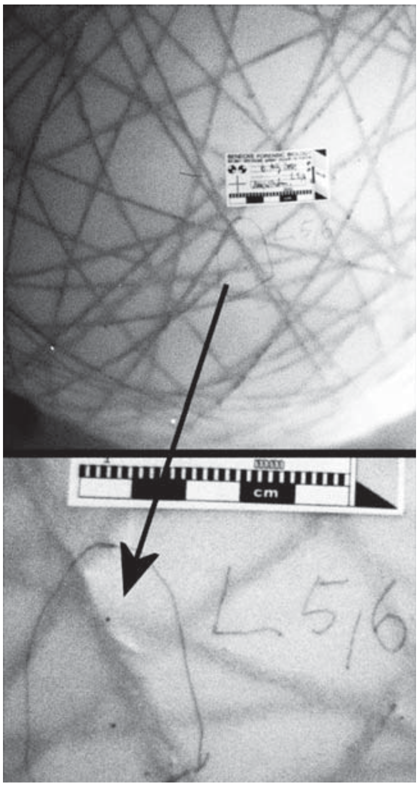

Fig. 4 Blood spatter-like droppings on a lamp hanging about 1.80 m over ground, produced by insects. Very small stains were found all over the lamp, on all sides, including top and bottom. Bottom: close-up of those stains. After Beneke and Barksdale, with permission [15].

Capillary action. Appears when the blood reaches a very narrow space, in which the surface tension and the adhesive forces are higher than the gravitational force, allowing it to flow in an antigravitational manner. They are usually linear, and present at the junction between two very narrow surfaces.

Void pattern. Appears when between the blood source and the surface is interposed a secondary object on which some spatters are projected. Therefore on the first surface can be identified an area in which spatters are absent [10].

Diluted bloodstains. They appear when at the scene there is a mixture between blood and other fluids (either external like water or internal like urine, or corticospinal fluid). The dilution attenuates the color and other properties of the blood but the genetic and serological data can still be identified is the dilution is not excessive.

Removed bloodstains. Even if no certain bloodstain is identifiable, by using photochemical agents (especially luminol), traces can be identified [14].

Entomological alterations. Can be identified using the criteria established by Beneke and Barksdale (see Table 1) [15], see also Figure 4.

Conclusions

Bloodstain analysis is off on uttermost importance for the forensic team which is present at the crime scene as it brings invaluable information about the circumstances and the kinetic of the aggressive act.

The analysis must be conducted with extreme care and detail, using both crime scene and laboratory related techniques, as the traces are often very difficult to identify but a correct identification and analysis can be crucial for solving the case.

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