Blood Pattern Analysis Aiding In Crime Scene Reconstruction – A Review

Aparna Dubey¹, Abhishek Saini²

¹Master’s Student of Forensic Science from NICFS,
²Manager at Dept. of Forensic Science & Criminal Investigation, Legal Desire Media & Insights

Abstract

The goal of forensics and crime scene reconstructions is simply to seek the truth. In pursuing this end, we revisit what we hope is a not-too-distant past and attempt to recreate the events that unfolded. Blood is the most prime and frequent evidence at a crime scene & can be found in various form; it can be present in dry bloodstain form, or in liquid form either in the form of a blood pool or in spattered form. The study of this spattered blood is what is call Blood pattern analysis. It is the forensic discipline that deals with the physics of the blood and assesses bloodstain left at crime scenes using visual pattern recognition. It is used to shed light on various forensic matter including reconstruction of events, digital diagnose of homicide/suicide/accident and identifying areas with high likelihood of offender m movements for taking DNA samples. Bloodstain pattern analysis (BPA) refers to the collection, categorization and interpretation of the shape and distribution of bloodstains connected with a crime. These kinds of stains occur in a considerable proportion of homicide cases. They offer extensive information and are an important part of a functional, medically and scientifically based reconstruction of a crime. Bloodstain pattern analysis is a discipline that has certainly reawakened to its role in modern forensics as another method of illuminating the “what” of crime. In this capacity, bloodstain pattern analysis acts as a critical bridge between classical forensic and crime scene reconstruction. A sequence of events may be recognized, and detailed questions with the reconstruction of the crime might be answered. No single forensic discipline has the potential to provide as much clarity regarding the occurrence at a crime scene as does bloodstains pattern analysis. That cannot, however, led to an expectation that the bloodstain evidence will stand alone. In the right hands, however, bloodstain pattern analysis is an extremely effective tool for defining the truth.
Introduction

The geometric interpretation of human bloodstain patterns at crime scenes is not a new idea, but it has acquired much greater recognition over the past several decades. Bloodstain pattern interpretation should be viewed as a forensic tool that assists the investigator or the forensic scientist to better understand what took place and what could not have taken place during a bloodshed event. The information obtained from the interpretation of bloodstain patterns may assist in apprehending a suspect, corroborate a witness’s statement, assist in interrogating suspects, allow for the reconstruction of past events, and most importantly, exonerate an accused. As with any tool, bloodstain pattern interpretation has its strengths and weaknesses. The interpretation will only be as valid as the information available and the ability of the examiner performing the analysis.

Properties of Human Blood

Biological Properties: Blood is the fluid that circulates throughout the body by way of the heart, arteries, veins, and capillaries. It transports oxygen, electrolytes, nourishment, hormones, vitamins, and antibodies to tissues, and transports waste products from tissues to the excretory organs. Blood consists of a fluid portion referred to as plasma that contains cellular components consisting of red blood cells, white blood cells, and platelets. When blood has had opportunity to clot, the fluid or liquid portion of clotted blood is referred to as serum. Red blood cells transport oxygen from the blood while white blood cells (leukocytes) assist with defense against foreign substances and infection. The nuclei of the white blood cells are the sources of DNA in the blood. Platelets are major components of the clotting mechanism of blood. In normal individuals, cellular components comprise approximately 45% of the total blood volume, which ranges in healthy adults from 4.5 to 6.0 liters.

Physical Properties: Exposed human blood is not unlike other common fluids. It will act in a predictable manner when subjected to external forces. Blood, whether a single drop or large volume, is held together by strong cohesive molecular forces that produce a surface tension within each drop and on the external surface. Surface tension is defined as the force that pulls the surface molecules of a liquid toward its interior, decreasing the surface area and causing the liquid to resist penetration. Blood, like all fluids, does not fall in a teardrop configuration. A passive drop of blood in air is created when the volume and mass of the drop increase to a point where the gravitational attraction acting on the drop overcomes the molecular cohesive forces of the blood source. A blood drop falling through air will increase its velocity until the force of air resistance that opposes the drop is equal to the force of the downward gravitational pull. At this point, the drop achieves its terminal velocity. The properties like surface tension, terminal velocity, cohesive force, viscosity, specific gravity are important to consider as these physical properties of blood makes it different from rest of the fluids and tends to maintain the stability of exposed blood or blood drops and cause them resist alteration or disruption.
Classification of bloodstains

In 1960, Dr. Jozef Radziki of Warsaw, Poland, published “Slady Krwi w Praktyce Sledczej” (Bloodstain Prints in the Practice of Technology). In this work, Dr. Radziki established three basic groups of bloodstains, based on their mechanisms of creation[^4]. They are:

1. Bloodstains resulting directly from extravasation — drops, gushes, and pools of blood
2. Bloodstains resulting from the application of various instruments — spatter, cast-offs, and patterns resulting from direct contact
3. Bloodstains resulting from the wiping or removal of blood.

Classification of Bloodstain Spatter by Velocity - There are three basic categories of stain groups based on the idea of the size of the bloodstain compared with the amount of force propelling that bloodstain[^5].

i. Low-Velocity Impact Blood Spatter: Low-velocity is considered to be a force or energy equivalent to normal gravitational pull up to a force or energy of 5 ft./s (5 ft. per second). The resulting stain is relatively large, usually 4 mm. in diameter or greater. Free-falling drops of blood affected only by gravity.

ii. Medium-Velocity Impact Spatter: Medium-velocity is considered when a source of blood is subjected to a force from 5 to 25 ft. per second. The resulting stains range from 1 to 4 mm. in diameter. These types of stains are usually associated with beating or stabbing.

iii. High-Velocity Impact Spatter: High-velocity bloodstains are created when the source of blood is subjected to a force with a velocity greater than 100 ft. per second. The resulting stain is predominantly less than 1 mm. in diameter although smaller and larger stains may be observed. These types of stains are usually associated with gunshot injuries[^6].

However, there are various ways in which blood stains can be classified. The classification most commonly used today is that of S. James, P. Kish and P. Sutton. It divides bloodstains into three categories: passive/gravity, spatter and altered[^5].

1. The first category describes bloodstain patterns that are formed under the influence of gravity. Such bloodstains are often described as passive. This group includes contact stains, which results from contact between two surfaces, of which at least one has blood on it. Contact stains often provide information about sequences of movement. Flow patterns, pooling/saturation and drip stains also belong to this category.

2. The second group called spatter includes spatters that result from active events such as a shot, as well as spatter that are caused by, for example, expiration or cast off from objects that are swung.

3. The third category contains all further stain types, such as blood clots and
diluted blood that results from the addition of other liquids.

It is important to appreciate that blood pattern analysis is not limited to recognizing the individual pattern. More sophisticated analysis is important for two reasons: First, the importance of the combination of bloodstain patterns and second, the already mentioned fact that different mechanisms can produce similar bloodstain patterns. The simplest example of this would be spatters [7]. They can result from blows to a bleeding object or an object with blood on it, but they can also be produced by expiration. For this reason, differential diagnosis, which must be considered in connection with the given bloodstain context, are an important aspect of bloodstain analysis [8].

Understanding the general terms relating to blood pattern analysis

*Angle of impact*: It is the angle at which a blood droplet strikes a surface.

*Arterial spurs*: These are large patterns created under pressure, but with less volume and usually more distinctive evidence of blood pressure rising and falling.

*Arterial gushing*: The large pattern of blood that is created when blood escapes an artery under pressure is arterial gushing. In this the increase and decrease in blood pressure is apparent.

*Clot*: A mass of blood and other contaminants caused through clotting mechanisms.

*Cast-off stains*: Blood that has been thrown from a secondary object (weapon or hand) onto a target other than the impact site.

*Drop Patterns*: Characteristic patterns present when blood drips into standing wet blood.

*Expiratory blood*: Blood which is spattered onto a target, as a result of breathing. This occurs when an injury is sustained to the throat, mouth or airway.

*Impact site*: It is usually the point on the body that received the blow or applied force, from which the blood was shed.

*Origin*: The point in space where the blood spatter came from.

*Parent drop*: The droplet from which satellite spatter originated.

*Projected blood*: Blood under pressure that strikes a target.
Satellite spatters: Small drops of blood that break off from the parent spatter when the parent droplet strikes a target surface.

Shadow or Void: When some object comes in the path of blood flow/spatter and target object remains unstained due to the presence of the object, the area which remains unstained is called void or shadow. If the object has been removed after the incident of blood spattering/flow, the shape of void indicates the shape of the object which obstructed the staining of target surface.

Skeletonized stain: The pattern left when an object moves through a partially dried stain, removing part of the blood, but leaving the outline of the stain intact.

Spatter: Bloodstains created from the application of force or energy to the area where the blood is present.

Spines: The pointed edges of a stain that radiate out to form the spatter.

Splash: Pattern created when a volume of blood in excess of 1 ml. strikes a surface at a low to medium velocity.

Swipe: The transfer of blood onto a target surface by a bloody object that is usually moving laterally.

Transfer pattern: The pattern created when a wet, bloody object comes in contact with a target surface, leaving a pattern that has the features of the object making it useful for identifying the object.

Target: The surface where the blood ends up.

Wipe: Pattern created when a secondary target moves through an existing wet bloodstain on some other object.

Basics of formation of blood spatter

(i) When blood leaves the body as a liquid, it follows the laws of motion and gravity. The blood drops behave in predictable ways when they strike a surface or a force act upon them.

(ii) Blood begins to clot after it leaves the body (clotting can occur within 15 minutes). Hence, if some blood spatters are found more clotted than others, it can indicate that multiple blows or gunshots occurred over a period of time. This can help in the reconstruction of a crime [5].

(iii) Blood spatters can also contain bits of tissue and bone. The type of tissue can help to determine the location and severity of the injuries sustained.

(iv) Blood may be dripped out, sprayed from an artery, oozed out through a large wound, or flung off a weapon raised to strike another blow. Blood trails are created, either in the form of smears when a bleeding body is dragged or in droplets when it is carried. Trails are also formed when a person is wounded and walks away leaving bloodstains along the way [10].

(v) The shape of the stain can illustrate the direction in which it was travelling and the angle at which it struck the surface.

(vi) The site of origin from which a bloodshed event occurred can be determined.
(vii) Breaking of a blood drop on impact with a surface is directly related to the texture of the surface. On a smooth surface, such as glass, stain with clean edges and shapes of proper proportion will be formed. A rough surface, like concrete, will break the drop irregularly and generate a stain with irregular margin.

(viii) Blood spurting from arteries may provide information about the location and severity of the injury, position of the victim when the injury was inflicted and any subsequent movement by the injured person. If the person was in motion when the blood leaked or spurted, or if the drops flew through the air and hit an angled surface, the drops generally look like stretched-out exclamation marks. The end of the stain that has the smallest size blob indicates the direction in which the source was moving. \[11\]

(ix) The absence of blood (void) where one would expect to find it, suggests movement or removal of objects and changes to the scene. Cast off patterns, or drops that are thrown off from a swinging instrument in the arc of the swing, can illustrate the position of the assailant when swinging a knife, or a club.

(x) When a drop of blood falls vertically at a 90-degree angle, a round stain is formed. As the angle of impact increases, the drop of blood becomes elongated and develops a tail pointing towards the direction of travel of the drop. However, if blood falls from a short distance (around 12 inches) the stain tends to be circular up to an angle of 45 degree \[12\].

(xi) By measuring the length and width of the stain and dividing the width by length (w/l), the angle at which the drop fell on the surface can be calculated.

(xii) If blood drops fall several feet straight down, the edges may become serrated, and the farther the distance from the source to the surface, the more prominent the serrations.

(xiii) A height of 6 ft. or more can produce small spurts that radiate out from the main drop. If there are many drops less than an eighth of an inch across, with no larger drop, then it may be concluded that the blood spatter probably resulted from an impact.

(xiv) Based on the aforesaid characteristics exhibited by the bloodshed during the
commission of crime or in accidents, the bloodstain pattern formed at the scene, on the vehicles and on the clothing of the victims or assailants can **corroborate** other evidence on the basis of which investigators can seek additional clues\(^{[14]}\).

**(xv)** Bloodstain patterns help the investigators to understand the positions and the means by which the victim and suspect moved, interacted, and struggled through the crime scene. With an understanding of what and how things occurred, investigators can focus on finding fingerprints, footprints, hair, fibers and other forms of trace evidence\(^{[15]}\). Hence, gaining insight from bloodstain patterns can strengthen interrogation strategies and provide a clear visual impression of the crime events during court proceedings.

**Crime scene analysis & Reconstruction using size, shape and directionality of Bloodstain**

The geometry of individual bloodstains will generally allow the analyst to determine their direction of flight prior to impacting an object. This is done by examining the edge characteristics of individual stains.

**Figure 1.2** - The direction of travel of these bloodstains is from right to left and downward, as determined by the characteristics of the leading edge of the stains \(^{[6]}\)

The narrow end of an elongated bloodstain usually points in the direction of travel. After the directionality of several bloodstains has been determined, an area or point of convergence may be established by simply drawing straight lines through the long axes of the bloodstains.

**Figure 1.3** - Representation of the point or area of convergence of bloodstains on a wall by drawing straight lines through the long axes of the stain \(^{[6]}\)

The point where these lines converge represents the relative location of the blood source in a two-dimensional perspective on the x- and y-axes. This area of convergence will be an area, not an exact point. The area of origin or the location of the blood source in a three-dimensional perspective can also be determined. By establishing the impact angles of representative bloodstains and
projecting their trajectories back to a common axis extended at 90 degrees up from the two-dimensional area of convergence along the z-axis, an approximate location of where the blood source was when it was impacted may be established [16]. Diagrammatic representations of convergence and origin utilizing the x-, y-, and z-axes are shown below.

**Figure 1.4- (A) the point or area of convergence with the x- and y-axes [6]**

If the angle of impact is 90 degrees, the resulting bloodstain generally will be circular in shape. Blood drops that strike a target at an angle less than 90 degrees will create elliptical bloodstains. A mathematical relationship exists between the width and length of an elliptical bloodstain that allows for the calculation of the angle of impact for the original spherical drop of blood [17]. This calculation is accomplished by measuring the width and the length of the bloodstain. The width measurement is divided by the length measurement to produce a ratio number less than 1. This ratio is the sine of the impact angle. The impact angle of the bloodstain can now be determined by either referring to the sine function in a trigonometric table or by using a scientific calculator with a sine function.[1]

**Figure 1.5 - Measurement of the width and length of bloodstains. [6]**
With a calculator, after dividing the width by the length, utilize the function key, arcsin, sin⁻¹, or inverse sine function, and the corresponding angle of impact will be displayed. For a circular bloodstain, the width and length are equal and thus the ratio is 1.0, which corresponds to an impact angle of 90 degrees. For an elliptical bloodstain whose width is one half its length, the width-to-length ratio is 0.5, which corresponds to an impact angle of 30 degrees.[18]

After establishing the angle of impact for each of the bloodstains, the three-dimensional origin of the bloodstain pattern can be determined. One method is to place elastic strings at the base of each bloodstain and project these strings back to the axis that has been extended 90 degrees up or away from the two-dimensional area of convergence. This is accomplished by placing a protractor on each string and then lifting the string until it corresponds with the previously determined impact angle. The string is then secured to the axis placed at the two-dimensional area of convergence. This is repeated for each of the selected bloodstains.[19]

Figure 1.6 - (A) Method of use of a protractor with the calculated angle of impact to determine the area of origin of a bloodstain. Figure 1.6 (B) Elastic strings placed at the base of selected bloodstains and projected along the z-axis to represent the three-dimensional point or area of origin of bloodstains.[6]

Remember that this calculated area of origin is always higher than the actual origin of the bloodstains because of the gravitational attraction affecting the spatters while in flight. This gives the analyst the maximum possible height of the blood source. In practical terms, the analyst is attempting to determine whether a victim was standing, lying down, or sitting in a chair when the blood was spattered.[20]. This method for determining the location of a blood source is not always necessary. For instance, if no
blood spatter appears on a table top or chair seat, but spatter associated with a gunshot is found on the underside of the table and chair, the obvious conclusion is that the victim was on or near the floor when shot. Common sense and quality observations will often resolve the question of where someone was when injuries were inflicted.

**Documentation of bloodstain evidence**

On many occasions, the degree of significance that may be attached to a given bloodstain pattern is compromised due to insufficient documentation. When documenting bloodstain patterns, attention should be given to the following points [5]:

- Accurately document the size, shape, and distribution of the individual stains and the overall patterns.
- Include measuring devices within the photographs.
- Use more than one mechanism for documentation, i.e., photographs, video, diagrams, and notes. This overlap should prevent anything of significance from being overlooked.
- If possible, collect articles of evidence that may contain significant or questionable bloodstain patterns.
- Utilize overall, midrange, and close-up macro photography when documenting bloodstain patterns. Photographs should overlap so that close-up photographs can be associated with their location within the pattern. Microphotography is also a useful technique to study small spatters. Bloodstain pattern interpretation is very visual, and high-quality photographs make it easy to illustrate the significance of bloodstain patterns to a jury.
- Complete the documentation in such a manner as to allow a third party to utilize the photographs, notes, diagrams, and video to place the bloodstain patterns and articles of evidence back in their original locations.

**Information revealed by bloodstain pattern**

The bloodstain pattern interpretation is a discipline which utilizes the sciences of biology, physics, and mathematics. The interpretation of bloodstain pattern can be done by direct evaluation of scene and/or careful study of crime scene photographs in conjunction with detailed examination of clothing, weapon, and other physical evidence [12]. The proper interpretation of bloodstain evidence is crucial where the manner of death is questioned and the issue of homicide, suicide, accident, or natural death is to be resolved in a criminal investigation. Relative to the reconstruction of a crime scene, bloodstain interpretation may provide information to the investigator in many areas. [11]

- Origin(s) of the bloodstains.
- Distances between impact areas of blood spatter and origin at time of bloodshed.
- Type and direction of impact that produced bloodstain or spatter.
- Type of injuries or wounds.
- Which injuries or wounds were inflicted first?
- Object(s) that produced a particular bloodstain pattern.
- Number of blows, shots, etc., that occurred.
- Handedness of assailant (right-handed/left-handed).
- Position of victim, assailant, or objects at the scene during bloodshed.
- Evidence of struggle at crime scenes.
- Movement and direction of victim, assailant or objects at scene after bloodshed.
- Whether the victim was in motion or lying still when the injury was inflicted.
- Whether the victim was moved after the injury was inflicted.
- How long ago the crime was committed?
- Whether death was immediate or delayed.
- Support or contradiction of statements given by suspects or witnesses.

Methodology

The Use Of Luminol Photography - Luminol is a chemiluminescent reagent that can be utilized both as a presumptive test for blood as well as a method of chemical enhancement of impressions in blood on various surfaces. It is an excellent search technique for latent bloodstains at crime scenes or those scenes where it is suspected that attempts were made to clean bloodstains from an area. Since luminol is applied by a spraying technique, wide areas can be efficiently searched for blood.[21]. The spraying device should be capable of producing a fine mist. Overspraying with luminol should be avoided. Bluestar™ is a luminol preparation developed by Professor Loic Blum in France that is extremely sensitive and stable and produces a very bright, long-lasting chemiluminescence. Photography of the luminol reaction with a 35-mm camera requires a wide open aperture (f-2.8 or f-3.5) at “B” (bulb) setting with an exposure time of at least 40 to 80 sec.

![Figure 1.7-(a) Area of room prior to the application of Luminol][6]

![Figure 1.7(b): Luminol reaction of blood photographed with digital camera][6]
Figure 1.7 (c): Exposure of the luminol reaction with flash after 27 secs [6]

**Scientific Working Group on Bloodstain Pattern Analysis (SWGSTAIN)**

The idea of a contemplative group assembled to discuss and intelligently address substantive matters concerning the forensic discipline of bloodstain pattern analysis (BPA) is not unique. The FBI Laboratory through its caseworking units and Forensic Science Training Unit (FSTU) has developed a Scientific Working Group (SWG) program for assembling such contemplative groups[18]. The Scientific Working Group on Bloodstain Pattern Analysis (hereinafter referred to as SWGSTAIN) serves as a professional forum in which local, state, and federal government bloodstain pattern analysis (BPA) practitioners and practitioners from related fields can share, discuss, and evaluate methods, techniques, protocols, quality assurance, education, and research relating to BPA. This forum shall address substantive and operational issues within the field of BPA and shall work to build consensus-based, or so-called “best practice,” guidelines for the enhancement of BPA [22].

**Discussion**

Each area of forensics provides insight and a glimpse into the past. Each has its own place in evaluating the aftermath of crime- the physical evidence. In the most classical sense, the majority of the forensic disciplines provide information as to the “who” of crime. Fingerprints, serology, and trace and fiber evidence allow the analyst to associate people or objects with a crime scene. Forensic pathology, on the other hand, has always been the primary link to the “what” of crime, providing insights to some of the events that occurred during the incidents.

Blood pattern analysis is a discipline that has certainly reawakened to its role in modern forensics as another method of illuminating the “what” of crime. Used properly, it helps establish specific events associated with violent crimes. In this capacity, bloodstain pattern analysis acts as a critical bridge between classical forensics and crime scene reconstruction. Through this review paper I have tried to provide an articulate and practical guide to the interpretation of bloodstains patterns and crime scene analysis/reconstruction explaining the scientific methodology involved in the process. BPA explains the complex mechanics of blood spatter analysis and addresses the dynamics of reconstruction, such as determining motion and directionality, convergence and point of origin, evaluating impact spatter bloodstains, the characteristics patterns of blood which aid in analysis and the proper documentation of blood stains and the reconstruction of a crime.

Bloodstain pattern analysis is not for the casual investigator, who intends only to graze the surface, find a quick answer, and
move on. The bloodstain pattern analyst is truly one who reconstructs crime scenes. As much he/she understands all the forensic disciplines. The analyst must be able to objectively apply each category of evidence to the situation, inferring as little as possible, but recognizing the whole. In this fashion, the evidence establishes a knowledge base from which the analyst knows the “truth”.

**Conclusion**

The goal of this review paper was to acquaint the reader with the basic concepts of bloodstain pattern interpretation. The interpretation of bloodstain patterns can become very complex, depending on individual case factors and thus we need a discipline to deal with it. BPA is that branch of forensics that deals with the physics, biochemistry of blood after it has been discharged from the body. It is used to shed light on various forensic matters including reconstruction of events, differential diagnosis of homicide/suicide/accident to create a difference between them. A major pitfall is oversimplification of this complex discipline. It is unfortunate that people fail to adhere to sound scientific practices and rely more on speculation than on fact. To become proficient in this discipline, one must have solid grasps of mathematics, physics, scientific method, and a great deal of practical experience. Anyone working in a field where bloodstains may later be used to incriminate or exonerate a suspect will find a solid working knowledge of what bloodstain pattern interpretation can and cannot do.

**References**

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