**D.U.Quark**

Volume 2
Issue 2 *Spring 2018*

Article 7

5-3-2018

# Bloodstain Pattern Analysis: Applications and Challenges

Dana Dryzal
*Duquesne University*

# Bloodstain Pattern Analysis: Applications and Challenges

**By Dana Dryzal**

*D.U.Quark* 2018(2) pgs. 22-29

Published May 7, 2018

Peer Reviewed Articles

**ABSTRACT**

When a violent crime occurs, blood evidence is found at the crime scene. Bloodstain pattern analysis is a subfield in forensic science that utilizes blood evidence to reach a conclusion about a crime. The shape and convergence of bloodstains can infer the murder weapon and origin of attack, which is crucial when reviewing witness statements. However, analyst error sometimes results in inaccurate conclusions. This review will focus on how blood is detected and classified and include certain factors that may affect blood appearance. Current classification methods will be discussed as well as new, emerging methods. Future research into analytical methods could allow blood pattern analysis to become a more reliable area of forensic science.

**KEYWORDS:** Bloodstain pattern analysis, luminol, DNA, impact spatter, directional analysis

## INTRODUCTION

Bloodstain pattern analysis (BPA) is one of the subcategories in the field of forensic science. Blood evidence is crucial in criminal investigations because it can corroborate or dismiss a witness's account of the crime. Additionally, because blood is rich in DNA, it can also be used to generate a DNA profile to match either the suspect or victim. Thus, it is imperative to have methods of blood detection that simultaneously preserve the genetic information. After the presence of blood is confirmed, it is then classified. In the 1960s, Dr. Paul Kirk made contributions to blood spatter analysis by categorizing blood by size and speed at which it hits the surface. [1-2] His description of velocity impact spatter being low, medium, and high is still employed in the field today. [1] While BPA is heavily relied on in the forensic science community, its validity is becoming questioned. The discernibility of bloodstain evidence can be difficult for analysts and is further complicated by other environmental and health factors that contribute to bloodstain appearance. To combat this problem, new, computerized methods are being tested to improve scientific accuracy and the reliability of the legal system.

## METHODS OF BLOOD DETECTION AND TESTING

To classify blood and perform a thorough analysis, its presence must first be detected and confirmed. Typically, analysts will first use the Appearance, Behavior, and Context (ABC) Approach to Bloodstain Verification because it can be impractical to test an entire crime scene for blood. [1] However, when chemical tests are necessary, they are utilized based on whether the suspected blood is visible or not. Often, blood is hard to detect, especially if criminals attempt to conceal the evidence by washing it away or using cleaning products. Fortunately, there are many tests to aid analysts.

*Visible Blood Testing Methods*

In the Kastle-Meyer test, a blood sample is treated with ethanol and phenolphthalein, a colored indicator. [3] When the solution changes from colorless to pink with the addition of hydrogen peroxide, blood is present. [3] While the Kastle-Meyer test is affordable and quick, it cannot be applied directly to the bloodstain because it destroys DNA evidence. [3] Thus, it would be best applied when there is ample blood evidence to perform other confirmatory and DNA tests. Alone, hydrogen peroxide is also useful because it produces white foam from the formation of oxygen bubbles by the catalase enzyme in blood, which can easily be observed. [4] Although hydrogen peroxide has low sensitivity, it is practical because it is affordable and does not interfere with DNA extraction, even after 30 days of chemical presence. [4]

*Invisible Blood Testing Methods*

While hydrogen peroxide is applied to visible blood, it is also employed when blood is hard to detect. It has the ability to change the color of blood, and the white foam also provides color contrast against dark surfaces. [4] This makes hydrogen peroxide best utilized on dark, hard-to-see surfaces because it makes blood easily visible. Additionally, infrared imaging analyzes bloodstains on dark surfaces. [4] Even though it does not use chemicals, its use is impractical because it cannot detect small blood stains. [3-4] Lastly, luminol is one of the most common methods used in blood testing and was first employed in 1937. [3] In darkness, luminol produces a blue-tinted chemiluminescence (glow) when exposed to hemoglobin in blood. [3-4] Luminol has been able to detect blood on surfaces that have been concealed by several layers of paint, and it is even successful on degraded samples while keeping the DNA intact. [5] Thus, luminol's high sensitivity makes it the most practical method of blood testing. Unfortunately, inconclusive results can result from factors affecting luminol including its age, preparation, storage, and measure of chemiluminescence. [6] One study concluded that even blank samples emitted low chemiluminescence. [6] While current methods still provide analysts with sufficient information, it is evident that more studies must be done to test luminol's reliability. Overall, further research may also provide analysts with a more affordable, sensitive, and consistent method for blood identification.

## CLASSIFICATION OF BLOODSTAINS

Once it is confirmed that blood is present at a crime scene, analysts can then classify it (Figure 1). Low-velocity impact spatters are produced when blood drips by gravity and are easily discerned by smooth edges and round appearance. [1-2] Medium-velocity impact spatter consists of a combination of large and small drops that travel faster than low velocity spatters. [2] Medium-velocity spatter is often accompanied by cast-off blood, since blunt-force attacks with an object are involved. [2] Lastly, high-impact velocity spatter occurs when high force is applied that sends the blood into a fine mist. [3] This type of blood spatter is caused by explosives and car accidents, although it is most associated with gunshots. [2] Transfer and smear blood are also typically found at crime scenes and can have several causes: hair, hands, fabric, footprints, knives, hands, etc. [2-3] Although there are many different ways of classifying blood, it isn't always straightforward. There are several factors that can pose a challenge for analysts and make for a difficult classification.

## FACTORS AFFECTING BLOOD STAIN PATTERNS

For forensic investigators, blood stains can be valuable in reconstructing crime scenes. Commonly, blood is used to determine the time that a crime occurred. However, there are many variables that can make interpretations difficult.

*Environmental Factors*

When one study varied relative humidity from 16-93%, it discovered that drying times of blood droplets were not significantly affected under 60% humidity. [7] However, because evaporation is difficult under high humidity, drying times were considerably altered when it was above 60%. [7] A similar study found the evaporation rate of blood droplets slowed as relative humidity increased from 12-66.5%. [8] The report also concluded that the morphology of blood and crack formation differed with varying relative humidity. [8] By examining the two studies, it can be decided that the drying of blood is directly influenced by relative humidity. One study was successfully able to predict the age of bloodstains up to one week by utilizing Ramen spectroscopy. [9] However, this testing method became increasingly inaccurate as the age of the bloodstain increased. [9] Although this technology could become a staple in the BPA community, there were several errors with this experiment: all environmental conditions were held constant, surfaces were not varied, and the volume of blood was also consistent throughout. Future research must be done to account for the various scenarios that blood spatter analysts may run into during investigations. Besides bloodstains, blood pools are commonly used for determining the time of the crime. It was determined that when all factors are held constant, blood drying occurs in five distinct stages, each with their own characteristics. [10] However, the temperature, humidity, substrate wettability (how easily blood can spread over a surface), and volume of pool can make it difficult to determine drying times. [10] The volume of pool can be further complicated if blood seeps into carpet or hair. [1]

*Health Factors*

Lastly, health factors may also play a role in drying rates. Anticoagulants can delay drying times through defective clotting, resulting in blood cells settling within a pool. [1] Additionally, alcoholics are more susceptible to viruses which expedite the settling of blood. [1] Thus, it is imperative for blood spatter analysts to be informed by the forensic pathologist of any health condition the victim may have suffered from. Lastly, expirated blood can often be misidentified as high-velocity impact spatter like that in Figure 1 because it produces a fine mist. [2] Exhaled blood results from injuries to the mouth, throat or lungs. [1-2] Because of these similarities, testing for saliva is sometimes necessary to determine if the blood was exhaled. [2]

Overall, there is an obvious gap in the field – much of the evidence is analyzed and interpreted by humans alone, leading to errors and false conclusions. Fortunately, research into new, automated methods could increase accuracy by applying numerical data.

## RELIABILITY OF ANALYSIS AND COMPUTERIZED METHODS

In forensic science, it is imperative to have scientists who are accurate to produce reliable results. However, human error is unavoidable. Because of this, automated methods are becoming an experimental subject in the forensic science community. For example, one study found that 20% of blood pattern analysts were incorrect when asked to identify a blood spatter. However, most incorrect analysts were novice and did not have extensive BPA training or courtroom expertise. [11] Although experts are not completely error-free, it is evident that there is a correlation between experience and accuracy when identifying blood spatter. Commonly, errors in identifying blood spatter evidence arise when the crime scene has overlapping stains that make each hard to distinguish. [12-13] An example is one case study, where a man was shot and decapitated. [14] Many different blood spatter types were present: high-velocity impact spatter from the gunshot, arterial spurts resulting from the decapitation, and low-velocity drops and smears from being dragged. [14] So, a crime scene may have a combination of blood spatter like that in Figure 1. One study applies an image-processing method that divides blood spatter into local and globular features which are assigned quantitative data. [12] Although more blood spatter types must be tested, statistical analysis could be applied to this data in the future to quickly distinguish between bloodstain patterns. [12] Multi-resolution 3D scanning is another tool that takes enhanced and accurate crime scene photos to be examined by analysts. [13]

Although this method requires little set-up time and limits the analyst's contact with the crime scene, is has high cost and long data-processing times. [13]

Not only can it be difficult to categorize a bloodstain, but finding the origin of one can also pose a challenge. Traditionally, stringing is used – a marker is placed in the center of each bloodstain along with a string.[1, 3] Using trigonometry, the attached string is then angled in the direction from which the blood came.[1, 3] Stringing is a tedious process that has problems regarding false areas of convergence. [1, 3] However, new methods are attempting to combat this drawback. HemoVision is a computer software that uses bloodstain markers and computer algorithms to determine flight path of drops and their areas of convergence. Although this method is time-efficient and eliminates manual measurements, it is only successful when all the blood spatter is on a single wall. [15] Directional analysis is another method utilized by analysts that finds areas of bloodstain convergence. One study sought out to improve this current method by employing a modified (trimmed) bloodstain mean and comparing it to two others: Ransac and arithmetic mean. [15-16] While the modified mean was most successful at determining area of convergence for random stains, there was no improvement when the stains were chosen by analysts. [16] This experiment was vital because it revealed the accuracy of current directional analysis methods. Overall, blood spatter analysis is improving by the automation of several methods. Yet, additional testing must be done to verify results and reliability.

## CONCLUSION

Bloodstain pattern analysis will most likely always play a critical role in forensic investigations. With the help of certain blood testing methods, (Table 1), analysts can not only properly identify areas of blood, but they can also extract DNA evidence from it. Afterwards, they can then categorize the blood so that events of the crime can be learned. Human-based methods of bloodstain pattern analysis are being questioned for their reliability and accuracy due to the confusion and error surrounding classification and convergence. Because of this, exploring computerized methods could greatly improve the quality of science and thus reduce the amount of false convictions in the future. However, further research needs to be conducted to provide a solid method of computerized bloodstain pattern analysis that can be utilized for all types of stains.

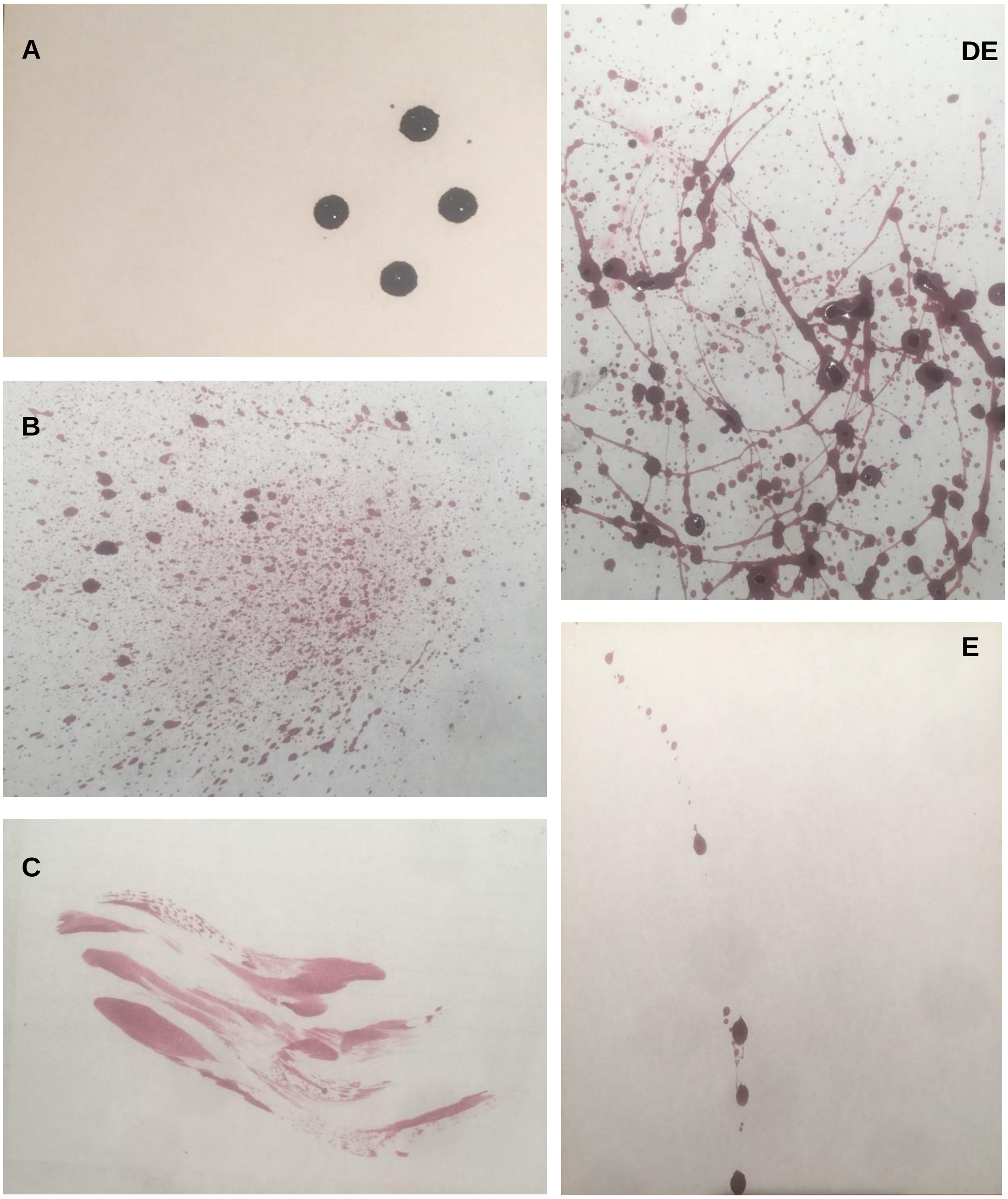


**Figure 1: Common types of blood spatter and transfer found at crime scenes.** A). Low-impact velocity drops are easily characterized by round, smooth edges and are produced by gravity. [1-2] B). High-impact velocity spatters are produced by a fine mist of blood, typically a result from gunshot wounds. [2-3] C). Swipes are a type of smear blood that have multiple causes, such as hair and hands. [2-3] D). Medium-velocity impact spatter has a combination of large and small drops resulting from blunt-force trauma. [2] E). Cast-off blood patterns often accompany medium-velocity spatters because of the blunt-force trauma. Cast-off is produced by blood flying off the murder weapon, such as a hammer or bat. [2]

**Table 1: The various methods of blood detection: benefits and ill-effects**

| Method | Positives | Negatives |
|---|---|---|
| Kastle-Meyer | Affordable, quick [3] | Destroys DNA evidence [3] |
| Hydrogen Peroxide | Affordable, no DNA interference, produces easily visible white foam/changes color of bloodstain [4] | Low sensitivity [4] |
| Infrared Imaging | No chemicals, no DNA interference [3] | Cannot detect small blood drops [3-4] |
| Luminol | High sensitivity, detects degraded samples, no DNA interference [5] | False positives, accuracy affected by age, storage, preparation [6] |

**References**


1. Wonder, A. Y. *Blood dynamics*, Academic Press: 2001.
2. Englert, R.; Passero, K. *Blood secrets: chronicles of a crime scene reconstructionist*, Macmillan: 2010.
3. Gunn, A. *Essential forensic biology*, John Wiley & Sons: 2011.
4. Finnis, J.; Lewis, J.; Davidson, A. Comparison of methods for visualizing blood on dark surfaces. *Science & Justice* **2013,** *53* (2), 178-186, DOI: http://dx.doi.org/10.1016/j.scijus.2012.09.001.
5. Nagesh, D.; Ghosh, S. A time period study on the efficiency of luminol in the detection of bloodstains concealed by paint on different surfaces. *Forensic Science International* **2017,** *275*, 1-7, DOI: http://dx.doi.org/10.1016/j.forsciint.2017.01.028.
6. Cassidy, B. M.; Lu, Z.; Martin, J. P.; Tazik, S. K.; Kellogg, K. W.; DeJong, S. A.; Belliveau, E. O.; Kilgore, K. E.; Ervin, S. M.; Meece-Rayle, M.; Abraham, A. M.; Myrick, M. L.; Morgan, S. L. A quantitative method for determining a representative detection limit of the forensic luminol test for latent bloodstains. *Forensic Science International* **2017,** *278* (Supplement C), 396-403, DOI: https://doi.org/10.1016/j.forsciint.2017.06.031.
7. Laux, D.; Ferrandis, J. Y.; Brutin, D. Ultrasonic monitoring of droplets' evaporation: Application to human whole blood. *Ultrasonics Sonochemistry* **2016,** *32* (Supplement C), 132-136, DOI: https://doi.org/10.1016/j.ultsonch.2016.03.003.
8. Bou Zeid, W.; Vicente, J.; Brutin, D. Influence of evaporation rate on cracks' formation of a drying drop of whole blood. *Colloids and Surfaces A: Physicochemical and Engineering Aspects* **2013,** *432*, 139-146, DOI: http://dx.doi.org/10.1016/j.colsurfa.2013.04.044.

9. Doty, K. C.; Muro, C. K.; Lednev, I. K. Predicting the time of the crime: Bloodstain aging estimation for up to two years. *Forensic Chemistry* **2017,** *5* (Supplement C), 1-7, DOI: https://doi.org/10.1016/j.forc.2017.05.002.
10. Laan, N.; Smith, F.; Nicloux, C.; Brutin, D. Morphology of drying blood pools. *Forensic Science International* **2016,** *267* (Supplement C), 104-109, DOI: https://doi.org/10.1016/j.forsciint.2016.08.005.
11. Osborne, N. K. P.; Taylor, M. C.; Healey, M.; Zajac, R. Bloodstain pattern classification: Accuracy, effect of contextual information and the role of analyst characteristics. *Science & Justice* **2016,** *56* (2), 123-128, DOI: http://dx.doi.org/10.1016/j.scijus.2015.12.005.
12. Arthur, R. M.; Humburg, P. J.; Hoogenboom, J.; Baiker, M.; Taylor, M. C.; de Bruin, K. G. An image-processing methodology for extracting bloodstain pattern features. *Forensic Science International* **2017,** *277*, 122-132, DOI: http://dx.doi.org/10.1016/j.forsciint.2017.05.022.
13. Hołowko, E.; Januszkiewicz, K.; Bolewicki, P.; Sitnik, R.; Michoński, J. Application of multi-resolution 3D techniques in crime scene documentation with bloodstain pattern analysis. *Forensic Science International* **2016,** *267* (Supplement C), 218-227, DOI: https://doi.org/10.1016/j.forsciint.2016.08.036.
14. Karger, B.; Rand, S.; Fracasso, T.; Pfeiffer, H. Bloodstain pattern analysis—Casework experience. *Forensic Science International* **2008,** *181* (1), 15-20, DOI: https://doi.org/10.1016/j.forsciint.2008.07.010.
15. Joris, P.; Develter, W.; Jenar, E.; Suetens, P.; Vandermeulen, D.; Van de Voorde, W.; Claes, P. HemoVision: An automated and virtual approach to bloodstain pattern analysis. *Forensic Science International* **2015,** *251*, 116-123, DOI: http://dx.doi.org/10.1016/j.forsciint.2015.03.018.
16. Illes, M.; Boué, M. Robust estimation for area of origin in bloodstain pattern analysis via directional analysis. *Forensic Science International* **2013,** *226* (1), 223-229, DOI: http://dx.doi.org/10.1016/j.forsciint.2013.01.030.

Dryzal, Dana. “Bloodstain Pattern Analysis: Applications and Challenges.” *The D.U.Quark*, 2, 2 (2018): 22-29. https://duquark.com/2018/05/03/bloodstain-pattern-analysis-applications-and-challenges/