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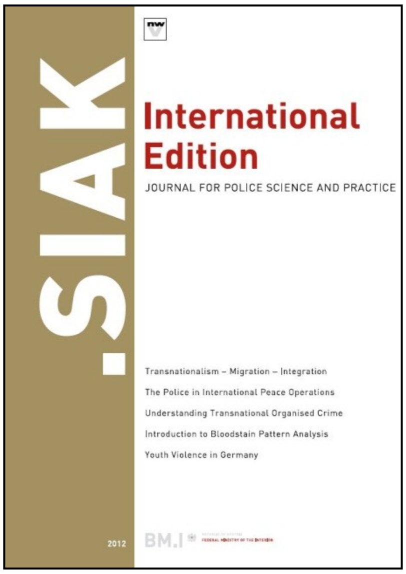

Brodbeck, Silke (2012):

Introduction to Bloodstain Pattern Analysis

SIAK-Journal − Journal for Police Science and Practice (Vol. 2), 51-57.

doi: 10.7396/IE_2012_E

Please cite this articel as follows:

Brodbeck, Silke (2012). Introduction to Bloodstain Pattern Analysis, SIAK-Journal − Journal for Police Science and Practice (Vol. 2), 51-57, Online: http://dx.doi.org/10.7396/IE_2012_E.

Note: A hard copy of the article is available through the printed version of the SIAK-Journal published by NWV (http://nwv.at).

published online: 3/2013

Introduction to Bloodstain Pattern Analysis

Bloodstain pattern analysis is a forensic discipline that deals with the physics of the blood and assesses bloodstains left at crime scenes using visual pattern recognition. It is used to shed light on various forensic matters including reconstruction of events, differential diagnosis of homicide/suicide/accident and identifying areas with high likelihood of offender movements for taking DNA samples. There are documented descriptions of bloodstain shapes at crime scenes that date back to past centuries. However, it was the Samuel Sheppard case in the USA that prompted advances in this field. Bloodstain pattern analysis is employed worldwide by scientists, police officials and medics in an interdisciplinary manner. Both the blood itself and the surfaces on which the bloodstains are found are important in the assessment of bloodstains. The umbrella organisation for bloodstain pattern analysts is the International Association of Bloodstain Pattern Analysts (IABPA), which offers various forms of membership. The name of the method (bloodstain pattern analysis) is often abbreviated to BPA.

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1. WHAT IS BLOODSTAIN PATTERN ANALYSIS AND WHEN SHOULD THIS METHOD BE USED?

Bloodstain pattern analysis (BPA) is the systematic assessment of the visual patterns of bloodstains at crime scenes based on the physics of fluids. Bloodstains are analysed according to shape, size and distribution. The method seeks to answer the question of how blood travelled through a given space to leave stains on a surface.

The most important uses of bloodstain pattern analysis include:

- reconstruction of the events of a crime or accident,
- verification of statements,
- in cases where there is doubt as to involvement in a crime,
- identification of areas with high likelihood of offender movement for the prioritisation of DNA samples,
- differentiation between homicides/suicides and accidents.

Bloodstain pattern analysis is based on principles of physics (essentially mechanics and the physics of fluids), in addition to biological, chemical and medical knowledge. Specialist training and qualification are necessary in order to practise as a bloodstain pattern analyst.

2. HOW DID BLOODSTAIN PATTERN ANALYSIS DEVELOP?

The history of bloodstain pattern analysis has two origins in the modern age. While there have been reports of individual cases and descriptions of individual bloodstain patterns for centuries, the first systematic study of bloodstains was published in 1895. Eduard Piotrowski from the University of Krakow published a study entitled "On the formation, form, direction and spreading of blood stains resulting from blunt trauma at the head" at the University of Vienna. Piotrowski covered the corner of a room with sheets of white paper and observed and documented the bloodstains that resulted from beating rabbits to death.

One of his findings was that bloodstains often appear with the second blow. Or in more modern phrasing, the condition for the appearance of bloodstains is the existence of a blood source. This observation still holds true in most cases, although exceptions are known (Brodbeck 2009; Brodbeck 2010a). Before this assumption can be applied, it is necessary to verify whether the spatter was in fact caused by blows or not. In other words, a differential diagnosis as to the cause of the spatter must take place first.

Piotrowski's work was followed by several publications that shed light on individual aspects of bloodstains, but did not lead to a systematic analysis. It later became clear that it is possible to calculate the angle of impact of spatter and its area of convergence using trigonometry. In the German-speaking world, works were published that identified the various stain patterns in a descriptive way, but without an underlying system.

The second acknowledged origin of the discipline is the "Samuel Sheppard case", which still remains one of the unsolved murder cases in the USA. Samuel Sheppard was convicted of having murdered his wife Marilyn Sheppard and was acquitted over ten years later on the grounds of lack of evidence. P. L. Kirk from the University of California at Berkeley gave expert testimony in the trial and went on to develop a research project based on the case. Later, the International Association of Bloodstain Pattern Analysts (IABPA) was founded and supported the continuing development of the discipline.

3. WHAT ARE THE BASIC PRINCIPLES OF BLOODSTAIN PATTERN ANALYSIS?

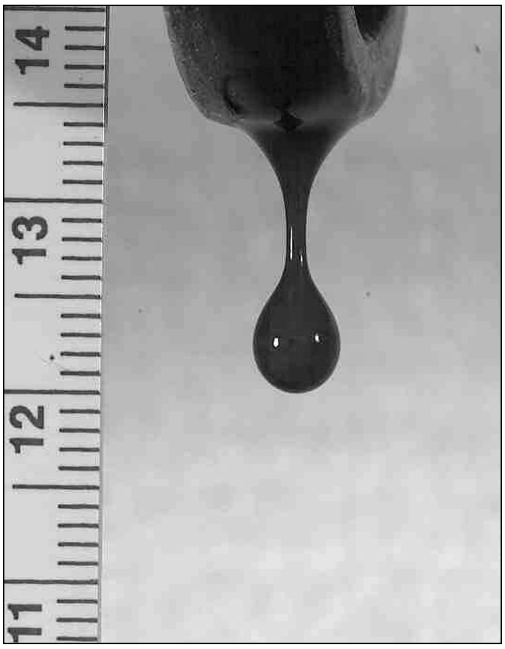
Frequently, when liquids in flight are drawn in everyday life, they are shown as having a teardrop shape. In reality, this is not the case. A liquid only takes the form of a drop when it drops from an object. Once the drop is airborn, it takes its minimal surface area and moves in flight in a spherical shape. Various physical forces such as air resistance and gravity act on it.

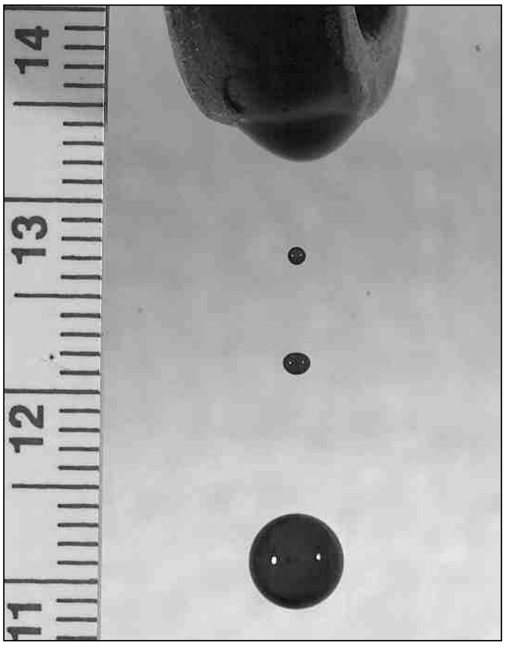
Gravity, for example, is responsible for the appearance of a number of patterns. It causes the so-called flow patterns. Flow patterns are formed by the movement of blood across a surface due to the influence of gravity. This stain type is widely known, but there are also other ways in which gravity acts on blood.

Large pools of blood, for example on solid surfaces, lead to serum separation. This means that the blood corpuscles sink because of their weight and the serum remains on the surface as a transparent liquid. Those unfamiliar with this phenomenon might think that liquid has been added to the blood. In reality, however, this is a non-manipulated blood pool, in which the blood was standing. Serious misunderstandings can occur, such as the idea that cleaning has taken place, whereas that is not substantiated at all by this type of stain.

A further difficulty is that in some cases different causes can lead to stains that look alike. For this reason, thorough knowledge of physics and bloodstain pattern analysis, and in particular of differential diagnoses, is essential in order to make an accurate assessment.

Source: © Epstein/Laber/Tayler[1]





Left – teardrop forms as blood drops from an object, right – airborne spherical form

It should also be noted that situations can arise in which bystanders are more bloodstained than the perpetrator. This can occur, for example, in cases when a weapon is swung overhead in a group of several people. Such cases are rare, but they are also an important reason for consulting a bloodstain pattern analysis specialist.

Source: © Blutspureninstitut

Multiple spatterfields of different origins with volume-related flow patterns show the direction of gravity

4. CLASSIFICATION OF BLOODSTAINS

There are various ways in which bloodstains can be classified. The classification most commonly used today is that of S. James, P. Kish and P. Sutton (James et al. 2005). It divides bloodstains into three categories: passive/gravity, spatter and altered.

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 result 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.

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

Source: © Blutspureninstitut

Complex bloodstain pattern with contact stains from hair, linear and parallel contact stains consistent with hands, spatters and passive drops

The third group 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 bloodstain pattern analysis is not limited to recognising the individual patterns. More sophisticated analysis is necessary 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 effect would be spatters. They can result from blows to a bleeding object or an object with blood on it, but they can also be caused by expiration. For this reason differential diagnoses, which must be considered in connection with the given bloodstain context, are an important part of bloodstain pattern analysis.

Since a description of all bloodstains would exceed the bounds of this article, I will describe cast-off patterns below by way of example.

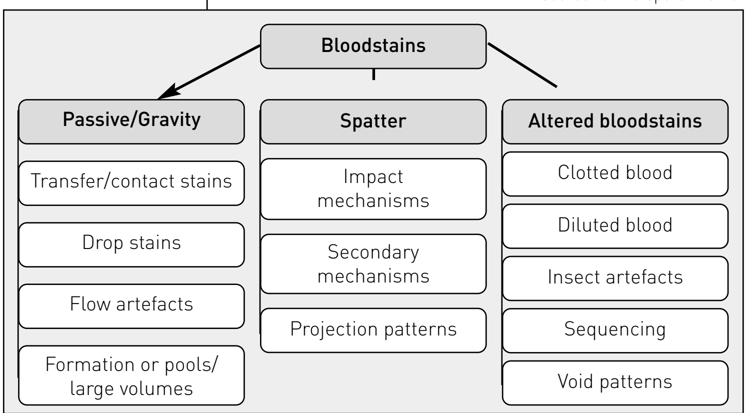
Cast-off patterns come under the second category of spatters and are in the group of projected bloodstains. These result from blood being cast off from a bloodied or bleeding object as it travels. They often occur in crimes involving blows.

These typically take the form of linear spatters, whose linear path shows the axis of the direction of movement and the droplets show varying angles of impact with the receiving surface. They are often found on the ceiling in the case of objects that are swung overhead, for example, but in principle they can be found on all surfaces in the given space.

Cast-off stains have two particularities, which often make assessments more difficult.

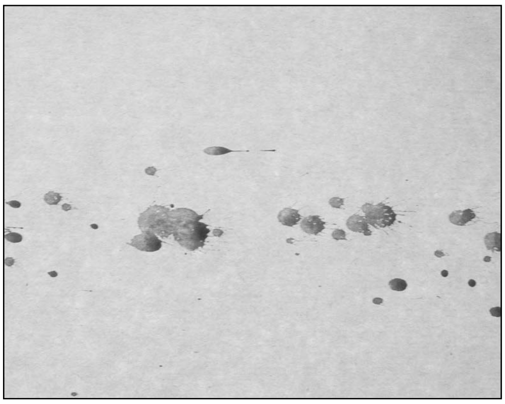
1. Since the bloodstains are distributed centrifugally, the offender often remains nearly or entirely unbloodied. There are cases of crimes of homicide with several deaths, when the perpetrator has remained nearly or entirely unbloodied. The blood physically follows the force that acts on it, which in this case is outwards.
   For this reason, there is no correlation between how bloodied the offender or their clothing is and the extent to which the victim is bloodied. Such a correlation is often assumed automatically, but it is often not correct, especially with regard to this bloodstain type.

Source: © Blutspureninstitut



Overview of the classification of bloodstains according to James et al. 2005

Source: © Blutspureninstitut



Cast-off pattern – Linear spatter caused by a bloodied block of wood being swung

2. The second difficulty is that situations can arise in which bystanders are more bloodied than the perpetrator. In these situations additional persons are physically present in the space where the blood travels. This stain type often demands expert assessment since persons with bloodied clothing might be innocent and the offender themselves might have no blood on their clothing. H. L. McDonnell and P. Kish summed up the problem with the line: "The absence of evidence is not the evidence of absence" (McDonnell/Kish 1996).

Statements made earlier about handedness are not applicable today. First, an object can be struck either with a forehand position or a backhand position of the hand. It is therefore possible for a blow to be struck on both sides of the perpetrator with either side of the hand. Second, a one-time blow made with the left hand is not evidence of left-handedness.

5. BLOODSTAIN PATTERN ANALYSIS AT THE CRIME SCENE

According to principles of forensic investigation, traces are secured at the crime scene in the order of their sensitivity. While in principle it is desirable for bloodstains to be assessed as soon as possible, bloodstain pattern analysis is also possible weeks, and sometimes even months later, without major limitations if the bloodstains are well-preserved. This depends on the surface that the bloodstains are located on and how well they are documented. Bloodstains that are exposed to weather effects, however, require analysis within a short time.

In order to assess how blood has travelled in the given space, a spatial understanding of the location is important. It is for this reason the bloodstain analyst visits the crime scene. Assessments made on the basis of photographs are relatively rare and limit the conclusions that can be drawn.

Both the areas at the scene of crime that have bloodstains and those that do not are important. This is clear by way of two simple examples.

The location of the bloodstains provides direct indications of where the action occurred in a given area.

If the action causing discharge of blood occurs at a point above the headrest of a chair, it is unlikely that the underside of the seat base will be bloodstained, unless there are other reasons for bloodstains. The same applies to the reverse situation if the action occurs at a point below the seat base. In this case, the upper surface of the seat base itself will not be bloodstained.

It is also possible to calculate the area of origin of spatters three-dimensionally in the given space. This is dependent on the phase of flight that the blood drops are in. The shape of droplets depends on their angle of impact on a surface. Pictures that show different shapes in the case of different angles oversimplify this question. The difficulty lies not in the mathematical calculation itself, which is a case of trigonometric relationships, but in the selection of which droplets to consider and the differential diagnosis of whether the spatter is calculable or not. Novices in the discipline often make mistakes in this respect.

Ideally, a bloodstain specialist is contacted in the early stages of investigation at the crime scene and the subsequent procedure is arranged.

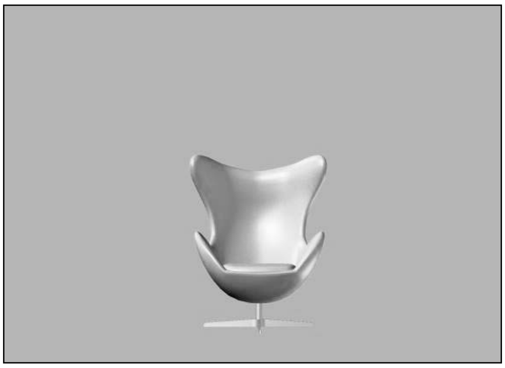
As to the crime scene, further procedures can take place in addition to regular analysis. For example, the use of forensic light sources for the detection of stains is standard today. Chemical substances can be used to enhance (amido black, leucocrystal violet) or detect (luminol, fluorescin) bloodstains.

In recent years, forensic supply has become highly commercialised, meaning that the chemical substances in question can be purchased commercially in a range of versions. In most cases, these are techniques that have long been known scientifically. One example is luminol, which is sold in tablet form under the name "Blue Star®". The chemical composition can be found on the package leaflet. In evaluating chemical methods, it is important to note that positive results from this method are not synonymous with evidence of blood. The chemicals can also react with other substances. A preliminary blood test is therefore necessary to verify the presence of blood when such methods are used.

Source: © Epstein/Laber/Tayler[1]

Active spatter created by the action of a hammer with dispersion of the fluid and central liquid lamella formation

Source: © Blutspureninstitut



A chair used as an example of the importance of spatial knowledge in bloodstain pattern analysis

Early and thorough documentation is important at crime scenes where discharge of blood occurs. In addition to the usual documentation, it is recommended that the exposed body parts of corpses (in particular the face, and inner and outer surfaces of the hands) be photographed before being packaged and taken away. In the age of digital photography, this is no longer an issue in terms of cost. Nor is taking high-resolution photographs a problem given the increasing memory sizes available.

Clothing should also be photographed. Bloodstains on body surfaces tend to be lost during transport, or are irretrievably covered by bloodstains during other transport. When corpses are transported, a great deal of information with regard to movement and position is irretrievably lost when unsecured evidence is left on the body.

The complete set of photographs of the crime scene is also important when preparing the expert report. Since blood is fluid before drying, often changes during investigation at the crime scene are later reconstructed by means of photographs. Changes occurring after discovery are in most cases no longer relevant to reconstructing the events of the crime.

Essentially, the expert report consists of a descriptive section, in which the bloodstains are described, and an analytical section, in which the expert evaluates the

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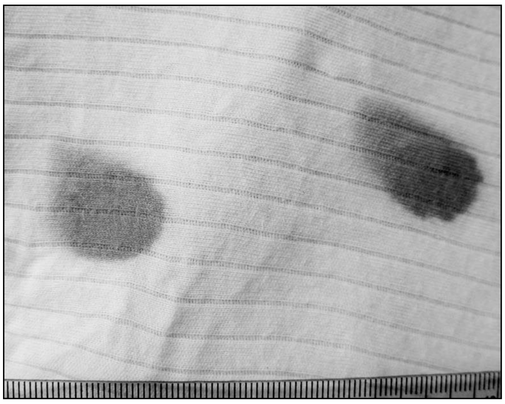

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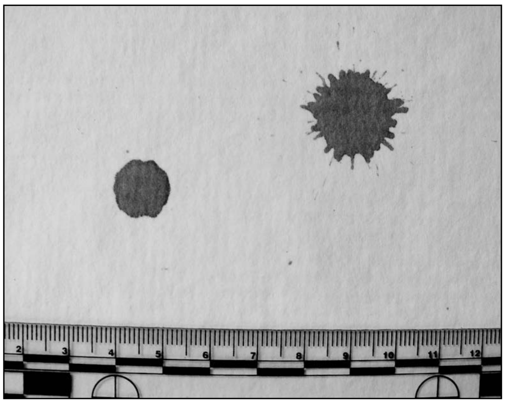

Both drops were created on both surfaces using the same physical mechanism. Left – damp cotton as surface, right – paper as surface

bloodstains. The expert must deliver an opinion regarding the surfaces on which the bloodstains were found and what state the blood was in.

It is important to note that the expert always has to address the questions of the surfaces involved. Both the type of surface and the state of the surface need to be considered. The formation of bloodstains and in particular their appearance are highly dependent on the surface in question. Contrast and surface structure play an important role.

6. SUMMARY

Bloodstain analysis is a forensic science that deals with how bloodstains arise after blood is discharged from the body. There are many cases in which its use is applicable, including at crime scenes, where DNA is of little or no informative value (for example, in the case of suspects who were entitled to be at the scene). It often serves to reconstruct events at the crime scene and to shed light on specific matters.

[1] The author wishes to thank Bart Epstein, Terry Laber and Michael Tayler for their kind permission to use the images shown here.

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