

## CRIME SCENE RECONSTRUCTION FROM BLOODSTAINS

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### INTRODUCTION

As it is common wisdom that eye witness reports or uncorroborated victim statements may be less than accurate, good crime scene investigation increasingly relies on science and technology to assist classical, thorough, patient detective scrutiny. In fact, it is now not unusual to have a team of 'experts' to assist detectives in their inquiries in major crime, ranging from forensic pathologists and forensic biologists to behavioural scientists. Indeed, a team approach is recommended.<sup>1</sup>

One of the most common types of evidence associated with crimes against the person is blood. Analysis of blood evidence offers two principal avenues of potential interest; namely, reconstruction of the crime scene and/or individualisation of the chemical characterisation of biological fluid stain may allow for exclusion of an individual as the source of a bloodstain at a crime scene, or inclusion, sometimes with very high levels of probability.

There are, however, numerous occasions when the importance of the physical characteristics of blood outweigh or complement the biochemical.<sup>2</sup> Three such cases were those of the State of Ohio vs Samuel H. Sheppard,<sup>3</sup> R. vs McLeod-Lindsay,<sup>4,5,6</sup> and the Morling Inquiry into the Morling Chamberlain Conviction.<sup>7</sup> Crime scenes, and those physical processes and activities directly instrumental in their creation, reflect both the trauma incident and the passage of time, to a lesser or greater degree. Consequently, analysis of physical evidence like bloodstain patterns may reveal a wealth of significant information.<sup>8,9</sup>

There are a number of scenarios where this may apply:

- (i) where the suspect legitimately came into contact with a (bloodstained) victim
- (ii) where the defence of the suspect is self-defence
- (iii) where a police member is shot or gets shot in a 'one on one' situation and there may be allegations of impropriety
- (iv) where there is a suspicious death (homicide versus suicide)
- (v) where two persons or more have bled at the scene and the blood may have mingled, or
- (vi) where there is a combination of the above.

Relatively little research has been carried out targeting the physical characteristics of blood whereas thousands of papers have been published in relation to the biochemistry of blood and blood markers. A crime scene examiner will strive to analyse bloodstain patterns at a scene in order to reconstruct the point of origin of flying blood droplets. The physical properties of blood drops which have produced a stain, and their history before and after deposition on the stained surface, are of fundamental importance in this analysis.

Once blood leaves the body with some speed (that is, venous seepage excluded), it essentially follows the laws of the physical sciences - notably those of projectiles in motion or

ballistics. Like all fluids, blood is held together by cohesive forces that produce a surface which is resistant to penetration or separation. Blood droplets are not dissimilar to water droplets in the way they may oscillate slightly or spin in flight, but the differences in the viscosity and surface tension of blood compared with those of water preclude sweeping analogies.

An examination and analysis of the number and pattern of bloodstains, their size, shape, location and the surface characteristics of that location at a crime scene may help provide the answers to a number of questions including those listed below. Information may be gathered on:

- (a) the origin(s) of the bloodstains
- (b) the distance between the target surface(s) and origin(s) at the time the blood was shed
- (c) the position and subsequent movement of the complainant/victim, the assailant and/or the objects at the time that the blood was shed
- (d) the type and direction of the impact(s) that produced the bloodstains
- (e) the minimum number of blows and/or shots
- (f) the order of deposition (of different stain patterns)
- (g) the anticipated damage to the victim
- (h) evidence of the deliberate removal of bloodstains
- (i) correlation with the subsequent postmortem and/or serological/DNA typing results in the case of multiple bleeders
- (j) tangible support for or disagreement with suspect re-enactments.<sup>10</sup>

#### BLOOD SPATTER ON CLOTHING

Blood on clothing poses slightly different problems from blood stains typically associated with a crime scene. As stated, the problem is one of determining the source of the blood. This may be satisfied by standard grouping practices but alternatively may require the forensic scientist to form an opinion from macroscopic and microscopic observations of the stain patterns themselves.

Questions which may be asked include:

- (i) is the stain a smear (secondary transfer) or is it spatter?
- (ii) is the direction of apparent stain travel the expected one?
- (iii) has the blood originated from the outside or the inside of the fabric?
- (iv) were the bloodstains deposited at approximately the same time?
- (v) if there is a blood stain over a second blood stain - was the initial stain wet or dry when the second was deposited? (This was of particular importance in the Chamberlain Royal Commission)
- (vi) could the blood have been rubbed off?
- (vii) could blood 'on the fabric of the wearer be transferred elsewhere, at what stage and in what fashion', that is, dropwise or by secondary contact only?
- (viii) has the blood stain been diluted and if so by what?
- (ix) are the stains associated with cerebro-spinal fluid (CSF), tissue or clotting?
- (x) how much blood was deposited on the clothing?

To address these points one at a time:

- (i) The stains versus smear aspect is arguably often the most important. A person may have legitimately come into contact with the victim whereupon any blood transfer should be of the secondary transfer or smear type. Spatter implies proximity with the victim at the time the victim was traumatised. The most important special case is backspatter particularly in relation to forearms. The issue in relation to blood spatter on clothing is sometimes primarily one of distance of the item of clothing from the source of the blood stain. In other words, it may be a measure of the culpability of the wearer of the clothing. Spreadsheet programs exist which allow the scientist to give estimates of the distance from the source that the blood drops may have travelled, prior to impacting on the target clothing.

To differentiate smear from spatter sometimes requires microscopic examination. Smears (transferred patterns) are usually larger in area or diameter than bloodspatter and often occur in closely related groups with clothing. The stain is seen only on the tops of the fibres of the weave. Conversely spattered blood is seen not only on the fibre tops but also in the "valleys" or recesses of the weave. Where absorption is limited, bloodspatter droplets may exhibit a raised edge and concave centre. The spatter (and indeed the smear) is often not indicative of direction simply because of the absorbency of the fabric. One should always be aware of direction, however, but interpret it with caution.<sup>11,12</sup> One has to be very wary about using trigonometric calculations where the fabric is absorbent, particularly with a limited number of stains.

- (ii) The term "direction of travel", refers in the main to the effect of gravity. The blood run should be downwards so that its direction may indicate if the body moved or was moved prior to its final resting place.
- (iii) Is self-explanatory and again may depend on the absorbency of the fabric and the number of articles of clothing worn.
- (iv) On occasion it is possible to hazard a guess as to whether stains were deposited at roughly the same time. The clue may be colour (methaemoglobin formation with time, which is brown as opposed to red-brown).
- (v) A secondary bloodstain may be due to 'contamination' of the article at the mortuary where a smear is obviously deposited over dry spatter, or because of secondary trauma perhaps a few hours after the primary trauma.
- (vi) Blood does indeed flake off some surfaces (for example nylon) and with such fabrics care must be taken in estimation of quantity of blood and in any movement of the article.
- (vii) A remote possibility also is that secondary blood can fall dropwise off absorbent fabric as the wearer moves and most likely when a large pool of blood is present.

- (viii) The blood is often diluted, for example, by rain, activities in the mortuary or deliberately by the assailant in the washing process. Note should be taken of the bloodstain typical colour and peripheral colour build up.
- (ix) A bloodstain may have a diluted appearance due to CSF contamination and/or might be associated with fragments of tissue or blood clots.
- (x) The volume estimate is best done by weight determinations if appropriate.

A further special case is that of **footwear**. Stains are often found on the soles of footwear worn in the area of a blood scene. A spattering of small droplets in particular on the uppers, however, can be very meaningful as it puts the wearer close to the crime at the time it was committed. Footwear used to cause bodily damage may also reflect that contact; inspection of eyelets, tongue, laces, stitching (usually absorbent) and where the uppers meet the sole, may reveal blood. The upper/sole joint is sometimes also useful for harbouring hairs or fibres caught in the crevices at the time of impact of the footwear with the victim. Shoes will of course also leave their tread in the blood; but any pooled blood that has been in contact with a shoe or a boot 'in a hurry' will also leave its mark.

#### **BLOOD SPATTER AT A CRIME SCENE**

Most if not all the questions that apply to blood on clothing also apply to blood at the crime scene itself. One major difference is that there will invariably be a number of different surfaces (substances) to take into account and a number of intersecting perpendicular planes on which blood may be deposited.

The second difference is that the crime scene will often be such that blood will be shielded by the walls, door or articles in the room from impacting on the expected surface given a particular direction of travel. This may indicate direction or status of moveable objects at the time of assault, such as a door or perhaps even an individual. This shielding effect is known as 'blocking' or occasionally 'shadowing' as a 'shadow pattern', devoid of blood. It is pertinent to the training of any crime scene officer that they are able to recognise the evidentiary potential of bloodstain patterns at a crime scene. As stated above, there are a number of areas where bloodstain pattern analysis is of particular value.

Special care must be taken where a victim is not killed at the scene. This situation causes additional complications if:

- (a) no body 'in situ'
- (b) massive contamination of the scene by police members, ambulance drivers etc.
- (c) 'long term' haemorrhaging and
- (d) aspiration from the mouth/nose.

#### **SPECIFIC SPATTER TYPE**

There are different types of spatter that leave clues as to their origin and assist with the reconstruction of the crime scene.

## Wipe and swipe (transfer patterns)

Head injuries will often cause the hair to become blood soaked. Movement of blood soaked hair against surfaces will cause characteristic **swipe** marks. Swipe marks on a surface such as a wall may indicate the position of an individual at some stage during an assault. Fine lines are caused by individual hairs, whereas more complex swipe patterns are generally caused by compression transfer of hair tufts. An object that is moved across a wet bloodied surface will cause a **wipe** mark on the unstained surface. At a crime scene, the most commonly detected wipe marks are caused by such objects as hands, feet, fingers and clothing.

As well as causing wipe marks, hands, feet, fingers and clothing will often leave distinctive patterns, like those caused by inked rubber stamps onto a surface. One of the most important patterns to be looked for at a crime scene or on an object collected from a crime scene is a fingerprint in blood. Many other patterns may enable the class characteristics of an object to be identified and in some cases individual characteristics may also be present. Shoe impressions are a case in point. A wipe mark on clothing can usually be detected by visual observation with a good light source. More difficult stains, or stains on dark coloured fabrics, often require the use of a stereomicroscope. Detection of a wipe mark on clothing is characterised by bloodstaining on the top surfaces of the prominent threads of the fabric and an absence on the recessed threads.

### Effect of velocity, surface and instrument

In early studies of bloodstain pattern interpretation, it was believed that a blood drop had a 'typical' volume of approximately 0.05mL or 50uL. While this volume might approximate that for blood dripping off some objects, for instance a finger, it does not necessarily represent the volume of blood dripping off other objects, such as knives, sticks or guns. Measurement of blood drop volumes falling from different objects demonstrated that there is not a uniform drop volume. In fact, the range has been shown to be at least 0.013 - 0.16mL.<sup>10</sup> Although the volume of blood leaving a finger or weapon is a function of the surface tension of the blood, it is also a function of the type, shape and area of the surface from which it departs.

The diameter of a bloodstain produced by a free-falling blood droplet, is a function of both volume and velocity. The distance the drop can fall will determine whether the drop reaches its terminal velocity. This is the velocity at which the force of gravity is balanced by the drag force and therefore when its acceleration is zero. For a drop of 50uL the terminal velocity is approximately 8 m.sec<sup>-1</sup>. Drops of smaller volume have a lower terminal velocity.

The target surface is important to consider when determining the significance of bloodstain size and shape. A droplet impacting on a smooth, non-porous surface at terminal velocity or less, will give a well-defined shape with little or no perimeter distortion. A droplet impacting on a concrete surface will give a stain with perimeter distortion which is sometimes associated with satellite spatter. At terminal velocity or less, the texture of the target surface has a greater bearing on the stain outcome than the velocity of the droplet itself. Informed interpretation of bloodstains is not possible, therefore, without considering the target surface texture.

### Generation of blood droplets

The different size of bloodstains is due to the different mechanisms used to generate their corresponding droplets. The stains can be characterised as one of three general types. These are not well defined and have considerable overlap, particularly when a few drops are analysed in isolation. The sizes of the droplets and the velocity ranges quoted are those of the author's experience but should only be seen as a rough guide. MacDonell<sup>13,14</sup> and Eckert and James<sup>10</sup> also quote sizes and velocities.

#### (i) Low Velocity

The stains are typically > 10 mm in diameter and are generated from droplets > 0.03 mL and which have a velocity < 5 m.sec<sup>-1</sup>. Low velocity spatter can be generated by a number of mechanisms, such as walking through a pool of blood, blood dripping into a pool of blood, blood dripping from a wound or by severing or breaking an artery. When an instrument is used to strike a bloodied surface, blood transferred onto the instrument can be "cast-off" during the deceleration of the back and forward swing actions. Depending on the speed of the instrument, these droplet stains may be classified as low velocity.

#### (ii) Medium Velocity

The stains are typically 1 to 8 mm in diameter and have a velocity of 5 to 50 m.sec<sup>-1</sup>. Medium velocity spatter is produced by the action of a blunt instrument striking a bloodied surface. This type of bloodspatter was of significant importance in the McLeod-Lindsay Case. The velocity of the instrument that strikes the target gives rise to a variety of droplet velocities some of which are 2-4 times the speed of the striking instrument.<sup>15,16</sup> The type of blunt instruments commonly involved in altercations are feet and fists or weapons such as wooden sticks, hammers, baseball bats and bricks.<sup>9</sup>

There is substantial experimental evidence which demonstrates that it is possible to generate considerable blood spatter whilst simulating an assault without acquiring any blood spatter onto the person 'perpetrating' the assault. Therefore the absence of bloodstaining on a suspect does not eliminate that suspect from the offence. A contact between a fast-moving blunt object and liquid blood on a surface, for instance a shoe striking a pool of blood or a hand slapping a wet wall leave staining with characteristic spines radiating out from the source of the energy.

#### (iii) High Velocity

The higher the energy of the source, the smaller the size of the drops generated. High velocity spatter is typically < 0.1 mm in diameter. Backspatter from a firearm travels at least 1.0 metre depending on the weapon, assuming a lack of wind.<sup>10,16,17</sup> When blood is projected upward onto a ceiling, it is almost always the result of a gunshot that had an upward trajectory such as the trajectory often associated with a suicide.

### **Blood dripping into blood**

When an injured person bleeds from a wound while remaining stationary, it is common to see the characteristic pattern of so-called 'blood dripping into blood'. Blood dripping into a shallow pool of blood generates distorted droplets which may not have time to assume a spherical-like shape prior to impacting a surface. Most of the stains formed do not exhibit direction. Those that do, usually point away from their source but some show the reverse direction; that is, they point roughly towards their source of propagation. The majority of droplets generated in this manner will not reach a height of more than 20 cm, but stains as high as 50 cm have been seen by the author in extreme circumstances. This evidence too, was particularly germane to the Loveday Inquiry into the McLeod-Lindsay conviction.<sup>6</sup>

### **Backspatter - detection in and on firearms**

Backspatter is a term used to describe blood or other biological fluids such as cerebrospinal fluid (CSF) that are directed back towards the source of energy that produced them. Consequently, the spatter may stain the hands, cuffs or firearm or any object close to the firearm at the time of discharge. The hands (and particularly the cuticles) and the firearm barrel and, where applicable, the chamber, should be closely examined for traces of fluids, as blood staining on skin is known to reflect the manner in which the blood droplets were created.<sup>18</sup> The elastic nature of the skin means that blood flakes are lost in minutes except in the nail cuticle area. An endoscope is particularly useful for examining firearms for spatter. Tiny spatter on clothing sometimes has a characteristic shape and may be found with the aid of a microscope adhering to the fibre threads.<sup>16</sup>

Backspatter is associated with close contact gunshot wounds to the head and face. It is rare for backspatter to result from gunshot wounds to the abdomen or chest, due to the usual presence of clothing. The droplets produced by this mechanism are typically very small and travel less than one metre. The cause of backspatter is not fully understood. It appears that rapidly expanding gas from a firearm, temporarily trapped within a buttressed space such as the skin and the skull, exits back through the entrance site towards its propagation source, together with biological fluids from the wound. Other poorly defined factors that may affect backspatter include the calibre of the weapon, type of ammunition, barrel length and anatomic features of the wound site. The presence of hair and clothing may impede droplet flight and reduce backspatter.

The author recommends that the forensic examiner attempt to duplicate any questioned pattern with a garment of similar fabric and the same weapon and ammunition. It may be relevant to the examination to construct a suitable target.<sup>10,19</sup> Also the relevance of this type of examination of hands and cuffs in relation to suicides should not be overlooked.

## Vascular Blood

### Arterial

Blood movement around the body is caused by the heart muscles contracting and forcing blood through the arteries. The blood pressure is at the maximum during the contraction and is termed systolic pressure. The minimum pressure is termed the diastolic pressure and is due to dilation, relaxation and filling of the arteries. During the contraction phase, the heart pushes 80-90 mL of blood in a wave-like movement, causing a pulse wherever the artery is close to the surface, due to the distending of the elastic vessel. Blood pressure is the force required to stop the pulse. Blood pressure in a child is approximately 100 mm Hg and in an adult approximately 130 mm Hg.

Most major arteries are located deep within the trunk or limbs of the body as a natural means of protection. The exceptions which interest the forensic practitioner are the carotid, the temporal, the femoral and the radial arteries. A bloodstain pattern resulting from a severed or breached artery will vary according to the size and the type of damage to the artery. The blood pressure in the severed artery will have a bearing on the distance the blood will be propelled. The higher the pressure, the further the blood will be projected.

If a large artery near the surface is nicked with a knife, then a characteristic fine spray will be generated. For larger breaches the pattern may be characterised by a series of sprays or arcs caused by the contraction phase and/or by large oval drops. Overlying tissue may restrict blood exiting the wound. A severed artery retracts into the wound and may significantly limit the volume of blood projected from the wound. In those instances where lungs have been punctured, air bubbles trapped in the blood may leave characteristic stains with circular areas of light staining within the actual bloodstain.

### Venous

In contrast to blood being projected from severed or breached arteries, the severing or breaching of veins is characterised by blood oozing from the wound. Many veins are close to the surface of the skin and are commonly damaged in assaults.

### Shadowing

Shadowing, shielding or blocking is a term used to explain the absence of blood spatter on a target surface due to an object being in a direct line between the source of the blood and the target surface. Together with string lines, it provides a very accurate and effective method to determine blood droplet origins in the X and Y directions.<sup>16</sup> It may also provide information in the Z direction depending on circumstance. Hand-held lasers provide a practical way of determining lines of sight. The stain pattern to Azaria Chamberlain's jumpsuit's sleeves/mittens clearly demonstrated that the sleeves had been shielded from staining (by the jacket).

### Expired blood

The experienced analyst is familiar with the characteristics and causes of so-called medium velocity bloodstains (above). In addition, the examiner will have an expectation in

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respect of the bloodstaining likely to be on the clothing of the assailant. A difficulty arises when the suspect assailant had legitimate cause to be close to or in contact with the victim. This was the case in the McLeod-Lindsay case. Consideration must then be given to alternative mechanisms for blood deposition on the suspect's clothing. For instance, bloodstains on a suspect's clothing may have originated from the mouth or nose of the victim in the action of either coughing or sneezing.

The expiration of blood from the mouth has been simulated by the author on a number of occasions both experimentally and in relation to particular cases. The blood droplets thus formed have typically been directional and of dimensions commonly associated with a medium velocity assault with a blunt instrument. It has also been shown that a cough will project blood droplets up to 3 - 4 metres without difficulty with the bulk of the expired material falling short of 2 metres. It is expected that blood 'sneezed' from the nose would in fact have a higher velocity still and may have the appearance of atomised droplets commonly associated with shootings or high-speed machinery. However, this is not an easy task to deliberately replicate.

### Chronology of stains

There are occasions where the sequence of events constituting a crime take place over a sufficiently lengthy period to leave evidence of a protracted time interval. This may typically occur when:

- (i) a first assault is followed by a second assault some minutes later
- (ii) an attempt is made to alter the position(s) of the victim(s) or items associated with the scene after the assault, or
- (iii) the victim is removed from the scene.

There are a number of 'indicators' which may assist the practitioner to make an informed comment as to the chronology of events or pattern depositions at the scene. This was particularly true of the patterns associated with the McLeod-Lindsay Inquiry. These include:

- (a) stains on clothing or surfaces that are associated with partial clots,
- (b) stains on surfaces that have dried sufficiently such that any subsequent contact with the stain causes smearing of only the interior part of the stain, leaving the perimeter of the stain (which dries first), apparently untouched,
- (c) changes of direction of blood rivulets coursing down a vertical surface which are brought about by dried bloodstains already on the surface,
- (d) separation of the plasma from the cellular material in a pool of blood on a horizontal surface,
- (e) a break or breaks in the continuity of a blood trail or pattern, and
- (f) blood that has dried and subsequently been dislodged by a further passage of events.

It is strongly recommended, where it may be crucial to the investigation or judicial proceeding that a time interval between two events be demonstrated, that, wherever possible, the hypothesis proposed be simulated using comparable conditions, temperatures, surfaces and so on for refutation or affirmation.

## CONCLUSION

In conclusion, a scientific approach to a crime scene is essential. The crime scene should be interpreted in the light of all the available evidence. The practitioner must strive to understand both the theory and the experimental data pertaining to bloodstain pattern analysis to be able to demonstrate and understand the limits and bounds of that evidence.

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