Use of Bloodstain Pattern Analysis to Investigate Crimes Against Wildlife

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Abstract: Blood "in flight" produces bloodstains in a predictable, consistent, and reproducible manner. At crime scenes investigators or analysts able to read bloodstains can with a high degree of certainty, reconstruct those forceful actions which caused the stain. Thus, those in specialized investigations trained in bloodstain pattern analysis can deduce the particulars of a crime perpetrated against humans or wildlife. Death investigators around the world—whether homicide detectives, law enforcement officers evaluating hunting accidents, or game wardens investigating wildlife crimes—may enhance the probability for success if they employ the established forensic discipline of bloodstain pattern analysis. Currently, only elite investigators drawing on every available means to crack a case implement this forensic discipline. Although not all experts agree on the implications of any given stain, all do concur that under controlled laboratory conditions that same geometric stain pattern can be reproduced in the laboratory.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 52:528–543

During an investigation, Geberth (1996) cautions that the professional police officer in general cannot possess a "lock and load" mentality, but instead, must have a flexible personality open to new suggestions. The detective must look for consistencies as well as inconsistencies and as new information is developed, he should be prepared to change the focus of the investigation.

The wise investigator refrains from forming opinions prematurely. He locates all potential sources for errors in interpretation. Preconceived notions and assumptions cause observational errors that lead to disagreement among officers at the scene of a crime or accident. In essence, nothing is self-evident unless that detective happens to be looking for it (Nordby 1992). In addition to employing their skills in other disciplines, investigators must consider the actions which may have occurred to create the geometric bloodstain pattern often found at the scene of a violent crime.

Blood Components

Blood is a fluid mixture of cells and plasma. In humans, blood comprises approximately 8% of the body weight. In various mammals, blood constitutes from 5.5% to 8% of the body weight. Blood ranges in viscosity between 4.4 and 5.5. For example, when one runs water through a measuring device, that liquid has a viscosity of 1. Blood flows 4.4 to 5.5 times slower than water when subjected to the same test.

Blood plasma is 91% water by volume and comprises 55% of the blood. Plasma can be broken down into general components of gases, salts, proteins, carbohydrates and lipids. The soluble proteins constitute about 8% of plasma; salts and organic acids comprise 1%.

The cells—formed elements—make up the remaining 45% of blood. The formed elements are red blood cells (erythrocytes), white blood cells (leukocytes), and platelets (thrombocytes). Bright red pigment is found within the blood's red cells. Oxygenated blood traveling away from the heart has a brighter color than blood returning to the heart.

White blood cells comprise less than 1% of the elements. White cells have nuclei and can analyzed by deoxyribonecleic acid (DNA) tests. The red cells have no nuclei and therefore do not aid the investigator seeking DNA evidence from such samples containing only red cells.

Application

Conservation police across the continent must often evaluate bloodstains from other than human sources. A veteran game warden of 25 years' experience now, I investigated a poaching incident a few years ago during deer season on a large southwest Texas ranch bearing "No Trespassing" signs.

Fresh footprints along several trails in a pasture filled with mesquite trees and prickly pear cactus indicated a single poacher had penetrated the property. The poacher had left few distinct footprints as he crisscrossed several cow trails attempting to find his downed quarry.

Though tracking was difficult on the hard ground, I soon discovered the decapitated body of a large mature white-tailed buck deer. The crook's sole motivation was to acquire the antlers as a trophy, leaving the venison. The poacher had removed the freshly killed deer's head still dripping blood, thus casting blood droplets on the ground, rocks, cacti, and grass. Judging from the particular patterns of these stains, I realized that in an attempt to disguise his direction, the poacher had walked backwards leaving the pasture. This ploy was especially evident when the footprints crossed bladed roads. However, the shape of the blood droplets on the ground and smears on one side of the leaves and stems of the brushy forbes indicated he had traveled the opposite direction from what the footprints first suggested.

Then, a few hundred meters from the deer's body, the poacher had apparently turned around, making little attempt to hide his "sign" or footprints. He had begun walking forward. Although the droplets were much smaller than a dime and spaced

several feet apart, correct bloodstain pattern analysis had allowed me to follow the poacher's true direction of travel. By so doing, I saved time and locked onto his escape route.

On another Texas case, in the early predawn hours highway patrol officers had arrested a traffic violator with an illegally taken deer. They took him to the county jail and called the game warden, who inspected the bed of the pick-up truck. The transfer pattern, a "fur mark," clearly showed that an animal with bloody pelage had been pulled over the side of the truck's rear fender.

The neck wound on the deer in the truck bed had bled very little. However, the bloodstain pattern tipped off the warden that the poachers earlier had hauled out yet a second illegal deer. After he confessed that he had poached 2 deer, the subject was convicted in court.

In another instance, a human death investigation, a surprised trucker discovered he had backed his trailer over a man's body and a bicycle at a supermarket freight loading ramp. Police erroneously concluded the victim had been killed and crushed by the truck's wheels as it backed down the approach to the ramp.

Following an incomplete autopsy, it was a bloodstain analyst's expert examination of the photographs of the victim and the analysis of the unusual blood stain patterns that revealed the victim had been dead and in full rigor mortis before discovery. The truck's wheels had never come in contact with the deceased. (Burnett et al. 1997)

History

Several European doctors studied and wrote about bloodstains in the late 1800s. Piotrowski in 1895 noted the correlation between the bloodstain's tail and possible direction of the droplets of travel. In 1901 Florence classified bloodstains caused by dripping, splashing, and spurting. In 1904 Gross devoted almost 30 pages to the investigation of stain patterns. Haberda in 1914 discussed a specific stain pattern associated with airway injuries. (Bevel and Gardner 1997)

In the early 1950s American criminalistics and biochemistry professor Dr. Paul L. Kirk in his book *Crime Investigation* included a chapter on bloodstain pattern analysis. In the famous state criminal case of Ohio versus Dr. Sam Sheppard, Kirk appeared in court as an expert witness and not only analyzed bloodstain patterns but contemplated the amount of time required for them to dry. Kirk thus demonstrated to the court that the murderer was right-handed. Dr. Sheppard was left-handed.

Reliability

The systematic development of bloodstain pattern analysis as a reliable forensic technique has been a major contributory factor in solving crimes involving bloodshed. Specific gravity, viscosity, and surface tension are important to understanding what happens to blood once it is removed from the body. Bloodstains result from forces acting upon liquid blood. When blood leaves a body by spatter or drop,

its behavior will follow laws of physical sciences, specifically that of ballistics—the science of projectiles in motion. (MacDonell and Bialousz 1971).

Conservation officers must use every forensic discipline available to explore criminal cases. Analysis of geometric bloodstain pattern, size, and shape may be useful in reconstructing events. Through study in blood experiments, bloodstain pattern analysts increase their knowledge.

Proficient bloodstain analysts can "read the sign" at a crime scene. Moreover, experience, observations made in laboratory study and experimentation provide investigators with insights sufficient to infer the force which produced the bloodstain.

Since thousands of experiments have established that blood droplets of the same size, velocity, and angle of flight react uniformly each time, bloodstain analysts can duplicate stain patterns and reproduce the same geometric stains under the same conditions time after time. Therefore, such reality has given bloodstain pattern analysis scientific validity.

Bloodstain pattern interpretation has suffered through a long period of neglect. As a result, investigators in death cases have not appreciated the obvious information available from this branch of forensic science. Failure to consider the significance of bloodstain evidence represents a serious omission in the investigation. Noted pathologist Paul Kirk ventured that, "No other type of investigation of blood will yield so much useful information as the analysis of blood distribution patterns" (Eckert and James 1993).

Blood Tests

Before we, as investigators, can begin to interpret the stain patterns of blood, we must first verify that these spots and marks are indeed blood. Suspected bloodstains could be wood stain, paint, or tar, for example. A multitude of tests have been developed to identify a particular stain as blood. The German scientist Schonbein in 1863 developed an effervescent reaction test using hydrogen peroxide. In 1868 Van Deen of Holland developed a color test using guaiac and hydrogen peroxide, this reaction producing a deep blue color. The benzidine test, introduced in 1904 by Adlers, reacted similarly, producing a blue color. Luecomalachite green, also developed by Adlers, replaced the benzidine test.

Additional presumptive tests for blood include the phenolphthalein test, which has been employed with the Takayama crystal test, discovered in 1912, or the Teichmann crystal test to confirm the presence of blood.

Another presumptive test, Luminol, when sprayed over bloodstains in darkness, emits luminescent light.

Presumptive tests react with blood but may also respond to certain other chemicals. For example, Luminol not only luminesces when contacting blood, but also gives off light when contacting copper, copper alloys, and vegetable peroxidase (Lytle et al. 1978).

Blood identification tests like the Ames (Miles) laboratory Hemastix product can now be purchased in a drug store. Designed for urinalysis, these reagent strips are

sensitive enough to detect as little as 5 to 20 red blood cells per microliter of water. Many investigators, myself included, carry the test strips in the patrol vehicle.

Lastly, scientists have used the high resolution and depth of field of the scanning electron microscope to aid in the identification of blood.

Predicting Age of Bloodstains

Drying time of blood is highly predictable and sometimes begins within 30 to 60 seconds after blood has left the body and is exposed to air (Pex and Hurley 1990). Without interference, the blood droplet will dry from the outer perimeter inward toward the center. Should the stain be disturbed prior to completion of the drying process, the resulting effect is referred to as "skeletonization."

If the drying stain is disturbed, wiped through by a finger or shoe for example, the border of the stain or its "skeleton" outline will remain visible. If the investigator finds disturbances within such stains, without evidence of skeletonization, he can place the time of disturbance very close to the time of stain creation (Bevel and Gardner 1997).

A gatherer of evidence attempting to estimate the age of bloodstain often relates the stain to the time a particular crime was committed. As blood ages, the color of the stain will change from red to brown. This phenomena is caused as hemoglobin oxidizes to the compound methemoglobin. Clearly, many chemical changes occur when blood dries and this continues as the blood ages.

There are several methods for determining bloodstain age, such as electron spin techniques, immunoelectrophoresis, and high performance liquid chromatography of HPLC. An HPLC system has applications for estimating the age of bloodstains on clothing (Andrasko 1997).

Determining Blood Origin

A number of analytical procedures have been established to distinguish animal blood from human. Scientists can use a form of immunology as an analytical tool

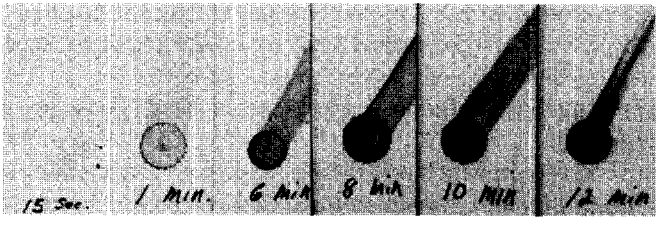

Figure 1. Skeletonized stains consist of only an outer periphery, the inner portion having been removed by wiping a partially dried bloodstain indicating activity or disturbance shortly after the blood was deposited.

(Small et al. 1976). In some states, wildlife officers with little or no previous experience in laboratory testing procedures have easily mastered an immunological technique to identify blood and tissue. Double diffusion or Ouchterloney analysis is a test named after its inventor, Dr. Orjan Thomas Gunnarson Ouchterloney, a Swedish bacteriologist.

Reliance on blood evidence is common in wildlife forensic science. A major difference is that blood evidence from humans comes from but one species and blood evidence from wildlife may come from one of many species. The primary limitations of immunological methods is that antisera is not available for many wildlife families.

The U.S. Fish and Wildlife Laboratory in Ashland, Oregon, publishing a sensitive and reproducible technique for inferring the blood source of 50 different animal species, used reverse-phase high performance liquid chromatography. This is useful in quantitative analysis of blood or mixtures of blood from different species (Espinoza et al. 1996).

Among human samples, scientists can frequently distinguish male from female. Additionally, free-flowing blood from a wound is distinctly different from menstrual blood in females due to the biological components of hormones and tissue debris from the uterus lining (Alsawaf and Tu 1985).

Bloodstain Pattern Analysis Tells Us What Happened

Physical evidence such as fingerprints, trace and fiber evidence, tool marks, and serological specimens can provide investigators with identities or the "who" of the crime, but bloodstain pattern analysis helps evaluate the "what" (Bevel and Gardner 1997) or "how" the action occurred at the time of the misdeed.

Almost never is the investigator of a crime present when the victim's blood is shed. Upon arrival at the scene, the examining official must scrutinize the site in order to determine what occurred or to confirm witnesses' accounts of the events.

In crime scene analysis, Rynearson and Chisum in *Evidence and Crime Scene Reconstruction* considered all evidence against time and surroundings. Tom Bevel (1991) not only weighed the nature and segment of evidence, but also the relational aspects to other segments and the time and sequencing aspects. To associate the scene, subjects and victim, he utilized the classic linkage triangle.

By accurate interpretation of bloodstains, the investigator may: 1) include or exclude a suspect; 2) determine the distance between the point of impact and the origin of blood at the time of bloodshed; 3) ascertain the type and direction of impact that produced these stains; 4) find the position of the victim or an object at the time of bloodshed; 5) learn of movement of a person or object after bloodshed; and 6) calculate the number of blows struck or shots fired to cause blood shed (Eliopulos 1993).

Dr. Herbert Leon MacDonell, considered by some the modern "father of bloodstain pattern analysis," and Lorraine Fiske Bialousz (1971) conducted extensive bloodstain pattern research. In blood flight experiments, the team found that under stabilized conditions, droplets impacting the target reproduced the same stain patterns with dependability.

Classification of Velocities

MacDowell obtained fresh blood from human donors and used the samples within 2 to 3 minutes. The team compared fresh blood samples to blood samples preserved with EDTA, citrate, and oxalate. All blood sample droplets, whether fresh or preserved, reacted similarly in flight tests. When measured, free-falling blood droplets reached terminal velocity or absolute dropping speed at 7.65 ± 0.15 meters per second (25.1 ± 0.5 fps) after traveling a distance of 4.25m to 5.5m (14 to 18 feet) (MacDonnel 1971).

Moving blood droplets are classified into 3 categories of velocities (MacDonnell 1971). Experts consider low velocity to be a force or energy equivalent to normal gravitational pull up to 1.5 meters per second (5 feet per second). For example, blood flowing from a person's arm or chin free-falls slowly downward drawn by the force of gravity. These stains are relatively large, ranging from 4 mm upwards in diameter. The blood may even puddle in a concentrated area below. The minidroplets splashed out of the puddle are categorized as "splashed blood."

Consider droplets falling a short distance, one on top of the other, to a small gathering puddle on a piece of cardboard on the floor. As the very small pool of blood begins to increase in size, minuscule fingers of satellite spatters radiate from the parent spatter upon impact as droplets fall into the accumulating pool of blood.

Of the second category, medium velocity bloodstains occur when a strong force impacts upon the exposed bloody area of a victim. For example, a blow by a handheld weapon to the head. The blood is propelled from the victim with each strike. These smaller patterns are easily distinguishable from large spots produced by puddling. Once the wound is opened, a smashing blow from a rock, a stick, or a fist to the victim can produce medium velocity blood droplets.

Experimenters have attempted, either by stomping a foot into puddled blood or by swinging a blood laden stick, to apply force exceeding 7.60 meters per second (25 fps) but they failed. "Medium velocity blood" refers to the force applied, not to the speed of blood in flight. Medium velocity stains are the result of forces applied to a blood source at a velocity not less than 1.5 meters per second (5 fps) nor more that 7.60 meters per second (25 fps).

In human crime investigations, medium velocity stains are nearly always associated with beatings or clubbings. Medium velocity bloodstains can also be found where wildlife, a wounded deer for example, has thrashed about while in the death

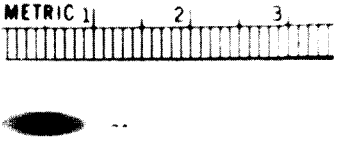

Figure 2. The tadpole-like tail of this medium velocity impact stain points toward the direction of travel and the head faces the source. This bloodstain indicates the droplet was traveling from left to right at the time of impact.

throes. Although medium velocity stains vary in diameter, the greatest number of stains range in size between 1 mm and 4 mm.

The third category, high velocity spatters, usually from a gunshot, appear in a mist-like dispersion similar to an aerosol spray. The "atomized" blood droplets, less than 1 millimeter in size, fly from the wound as the bullet exits. The fine particles can be interspersed among the larger stains and tissue. High velocity spatter results from forces applied greater than 30.5 meters per second (100 fps).

Terminology

Many people erroneously believe that a bullet penetrates an animal or person much as a drill bit bores through a wooden plank. Actually, the bullet moves through the body imparting kinetic energy to the surrounding tissue which is flung away from the bullet's path radically causing a cavity that is much larger than the bullet. The cavity expands, then collapses in 5 to 10 milliseconds to 5 to 10 thousandths of a second (Di Maio 1985).

"Backspatter" occurs in certain types of gunshot wounds and can be reproduced in mock experiments. Backward spatter of blood is most commonly associated with gunshot wounds of the head. Starburst or stellate entrance wounds, in which a blow-back effect creates a pocket-like space within the scalp, are commonly associated with backspatter. The actual backspatter occurs when the skin is stretched by high pressure with resulting rupture in a characteristic cruciate (or cross-shaped) fashion or enlargement of the wound so that blood is released around the side of the muzzle. The accelerating force is the backwards stream of escaping gas trapped between the elastic skin and the rigid skull (Stephens and Allen 1983).

In cases involving shootings wherein the firearm's muzzle has been held in near contact to the victim at the time of firing, a phenomena known as the "drawback effect" is sometimes present. Many experts hypothesize that the overpressure in the wound allows the blood to be propelled backwards toward the momentary vacuum created in the barrel as the bullet exits the firearm's muzzle.

Blood and tissue have been found inside gun barrels in cases involving contact or near contact wounds. The heaviest concentrations of blood were found near the muzzle. Penetration inside the barrels ranged from 2.54 cm (1 inch) for .22 caliber revolvers to 12.7 cm (5 inches) for shotguns (Eckert and James 1993).

Before the investigator may begin to learn bloodstain pattern analysis, understanding definitions accepted by the International Association of Bloodstain Pattern Analysis is helpful.

1) "Target," refers to an object onto which blood is splashed, spattered, projected or dropped. In the laboratory the target is usually white cardboard. However, "target" can also mean any object receiving blood spatters under circumstances other than lab conditions.

2) "Impact site" is usually that point on a bloody object which receives some form of blow or gunshot but can also be defined as the target surface that has been struck by blood.

3) "Cast-off" bloodstain patterns result from a whiplike motion as the liquid blood is propelled from the end of a weapon, such as a stick swung overhead. Blood cast-off indoors from a bloody object swung overhead always produces characteristic ceiling stains.

For example the first blow to the victim's head with a pipe starts the bleeding. The second and subsequent blows coat the pipe with blood. At the peak of each backswing the rapid deceleration causes the blood to be cast off. Practically no blood will be thrown off the weapon as the assailant swings the pipe forward. A forward swing never produces the same pattern, even if the same amount of blood is carried on the weapon.

Within enclosed structures, experts have calculated the minimum number of blows the assailant struck the victim by counting the trails of stains on the ceiling. This "cast-off" blood is classified as medium velocity.

While investigating fist fights, the police investigator is wise to look for medium velocity spatters of blood on the attacker's shirt cuffs and collars, hands, wrist watch, and ring. The game warden is advised to check the same areas on a suspected poacher which may bear small cast-off stains occurring while moving or field dressing game.

4) A "smudge" is a bloodstain that has been altered or distorted by contact with a non-bloody surface. Classification of this type stain is impossible. Smudges can be caused by movement of the victim or the assailant.

5) A "wipe pattern" is caused when an object has moved through a wet bloodstain removing blood and altering the pattern.

6) A "transfer pattern" is caused when a bloody surface comes in contact with another surface. An example is when a bloody hand comes in contact with a car door or wall. Another instance may be found when a suspect steps in blood and transfers blood to the brake pedal.

7) "High velocity" blood spatter usually results from gunshot but has sometimes been reported in automobile accidents. This type pattern holds an extremely high percentage of fine specks of blood. High velocity blood receives impact at 30.5 meters per second (100 feet per second) or greater. The higher the projectile velocity, the greater the speed of the blood particles. Particles of vaporized or atomized blood do not exceed a forward horizontal distance of about .91 meters (3 feet).

High velocity blood particles are not always found at accidents, hunting incidents, and murder scenes, but when they are found, the investigator can be sure the stain is caused by gunshot. Bone fragments, tissue, and substantially larger diameter blood stains are often mixed in with the smaller mist-like droplets.

When a projectile strikes a target, sufficient force is transferred to the wound or any bloody surface thus creating spatter in the form of a fine aerosol of blood droplets. The droplets resulting from such an impact radiate in a 3 dimensional pattern that investigators refer to as a "cone-shaped" pattern.

The distance blood droplets will be cast when a weapon is held horizontal and perpendicular to the nonbloodied target depends on droplet size. The larger droplets travel further, the mist-like particles travel the shortest distance. Research has

determined this to be caused by air resistance inversely proportional to the size of the droplet. The closer the impact area is to the target receiving the stains, the higher the number of concentrated stains (Bevel and Gardner 1997).

High velocity backspatter can produce a pattern on the shirt cuff of a shooter in a contact or near-contact shot. Backflight comprised of droplets less than 1 mm in size is limited to about .61 m (2 feet) (Pex and Vaugn 1987). Examples of backflight blood have been found at wildlife crime scenes where the poached animal had been impacted by a high velocity rifle projectile.

"Expiratory bloodstains" can sometimes be confused with high velocity stains. In many situations the victims lungs, nose, or mouth may be filled with blood. As the victim coughs or gasps, air is forced outwards. The resultant pattern, comprised of small droplets, may mimic either medium or high velocity bloodstain patterns. By misidentifying the pattern, thinking it was caused by another event, or by failing to recognize expiratory blood, the analyst can easily be led astray in the analysis (Bevel and Gardner 1997). Expiratory bloodstains found where a deer has been poached will often contain pinkish flecks of lung material.

The "flight path" is the direction taken by a droplet of blood. The flight path may be defined by both the impact angle and the directional angle in consideration.

"Origin" is the point in three dimensional space where the blood droplet originated. This may be on the tip of a bludgeon where the droplet detached from the weapon and flew through the air or the origin could be droplets falling from a part of the victim's body, such as the chin.

Classification of Bloodstain

Bloodstain can be grouped into 3 classifications: passive stains, transfer stains, and projected or impact stains (Bevel and Gardner 1997). Passive stains can include clots, drops, flows, and pools. Impact stains include patterns such as spatter, splashes,

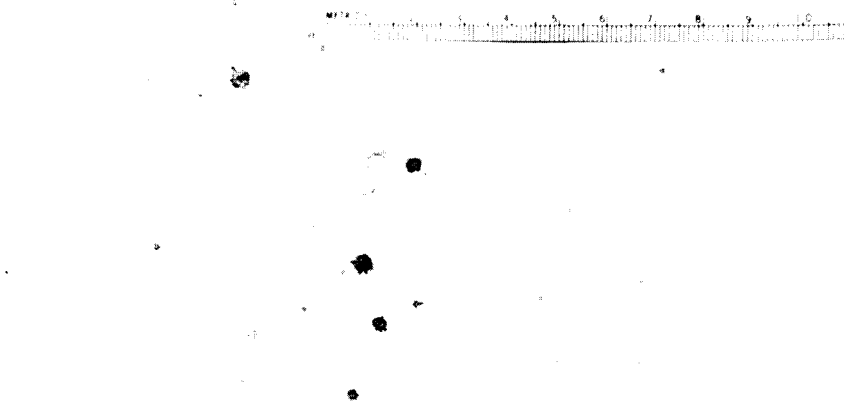

Figure 3. The preponderance of bloodstains will consist of small spatters ≤1mm in high velocity blood spatter.

cast-off stains, arterial spurts, and gushes. Transfer stains are comprised of pattern such as wipes, swipes, pattern transfers, and other contact stains.

The adhesive or "sticky" quality of blood is evident when one touches it. When falling through the air, a blood droplet forms a sphere rather than assuming a teardrop shape and is held together by surface tension. Once the droplet is in motion, it does not break apart.

Applicable to blood flight—but only in a general way—several scientific articles relating to the shape of raindrops are instructive.

McDonald (1954) discussed reasons raindrops are spherical in shape: "Surface tension always tends to reduce the surface of a free mass of liquid to the smallest area it can achieve." He explained, "An isolated drop of liquid not distorted by external forces is pulled by its surface tension into a spherical shape." However, this finding applies only to small raindrops of 1 mm in size or less. Larger drops were unable to maintain the perfect sphere shape in flight. Of these larger drops, said McDonald, they were "hamburger bun" in shape.

Elliott and Ford (1972) stated that increasing the size of a falling droplet has an effect similar to increasing the height from which it fell. The impact energy, dependent on both mass and velocity, determines the spreading velocity.

In his preliminary experiments, Herbert MacDonnell (1971) determined free-falling blood droplet volume averages about 0.05 ml. However, in more recent experiments, researchers have found disparate variations in droplet volume ranging from 0.013 ml to 0.16 ml, depending on whether the droplet fell from a fingertip, a knife blade, or saturated cloth.

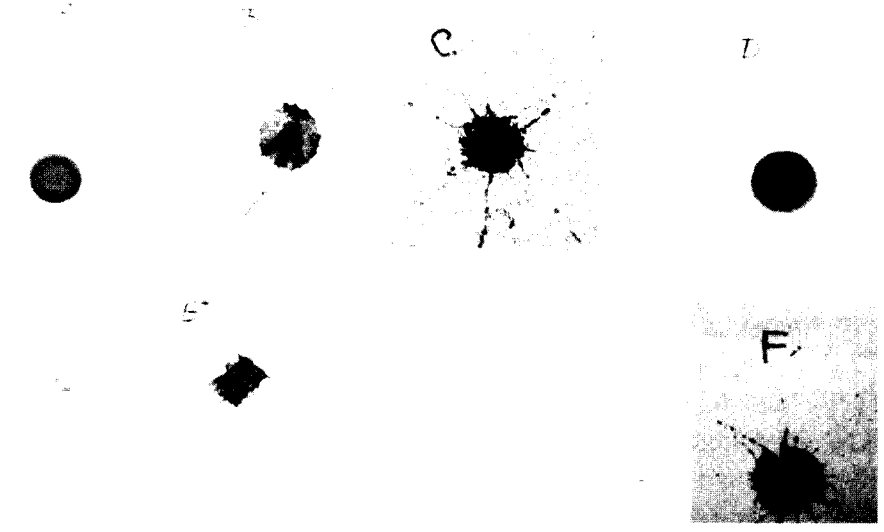

Figure 4. The target surface influences the bloodstain's shape: A = smooth rigid clear plastic, B = newspaper, C = sandpaper, D = smooth white cardboard, E = paper towel, F = pasteboard box.

Pizzola et al. (1986) conducted tests involving high speed photography of blood droplets in flight and ascertained that the falling height of a blood droplet could not be determined from the stain pattern unless he knew the volume of the droplet.

The action that causes a liquid to anchor itself to a solid object and allow itself to be stretched is called "capillary attraction." When a bloody thumb and forefinger are pressed together, the visible anchoring of the blood with the subsequent bridging effect demonstrates surface tension (Bevel and Gardner 1977).

Target surface texture influences the shape of impacting blood droplets. A blood droplet colliding at 90° onto a piece of rigid plastic maintains a smooth stain outline around the perimeter. The stain pattern remains basically the same regular round geometric shape whether falling 45 centimeters or 5 meters (roughly 18 inches or 18 feet). However, a droplet of the same volume impacting a rougher surface such as a paper napkin or piece of sandpaper shifts radically in surface shape, giving the stain an irregular shape.

Blood striking a smooth flat surface will assume one or two general shapes, round or elliptical. The bloodstain will be round if the droplet has impacted horizontally or fallen straight down at an 90° angle. The extent of a stain's degree of circular distortion becomes more elliptical or elongated as the angle of impact becomes more oblique from 90° to 0°.

In experiments, researchers found that stain patterns left by drops projected with a horizontal component of velocity impacting horizontal surfaces were identical to those left by drops falling vertically onto inclined surfaces (Pizzola et al. 1986). In other words, a droplet of blood impacting a target placed flat on the floor after being propelled away from the subject at a 10° angle will make a stain of the same shape

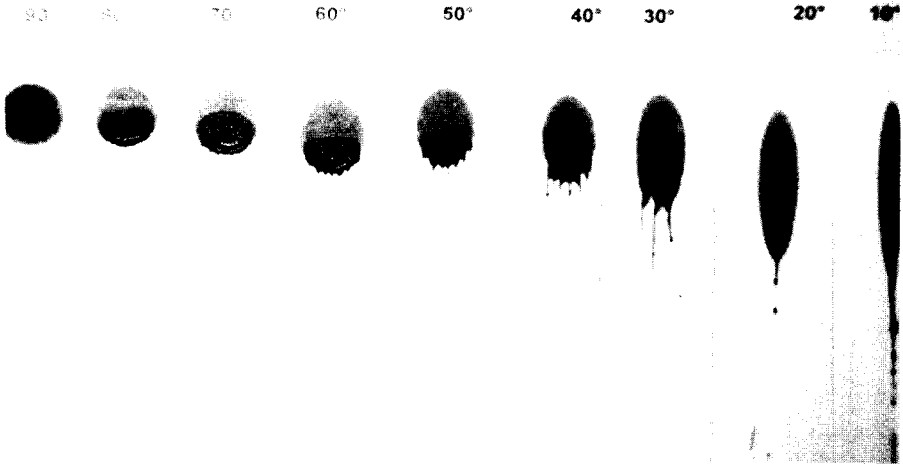

Figure 5. Stain elongation occurs when the angle of impact decreases from 90° to a more oblique 10°. Single drops of blood, 0.03 ml. volume, fell approximately 1m onto smooth cardboard.

and size as a droplet of the same volume released straight down on a target tilted at 80°. The degree of droplet distortion is directly proportional to the angle of impact.

A droplet falling at a 90° angle onto a surface tilted at a 45° angle will produce an elongated stain the same as that of a droplet approaching at a 45° angle and impacting a flat horizontal surface provided of course, that the targeted surfaces are of the same material. The same height and width ratios are used to figure an angular drop to a horizontal surface as a vertical drop to an angular surface.

A cast-off blood droplet hitting at an angle rolls along the targeted surface much like an ocean's wave. As the droplet moves across the surface it becomes tear drop or tadpole shaped. The "head" points toward the stain's origin and the "tail" points in the direction of travel.

The only exception to this rule of directionality is in the case of a cast-off or satellite spatter thrown off from a larger drop or pool of blood. These cast-off droplets still resemble a tadpole or tear drop but the "tail" or sharper end points back to the origin. Since the satellite spatters travel only a short distance, mere centimeters or fraction thereof, they can easily be traced back to the parent drop or source and are not easily confused with other types of cast-off droplets.

Impact Angle

A French medical paper explored the length-to-width ratio of bloodstains as a function of impact angle. Baltzhazard, the author, cautioned that the mathematical formula for calculating angle should not be depended upon for precision. However, the writer did say that the curve permits an estimate for impact angle with acceptable accuracy (Blatzhazard 1939).

Since there is a mathematical relationship between the shape of the bloodstain and the angle at which the blood droplet has impacted a surface, the investigator can compute the angle of impact. However, precision of the math should not be construed to mean a similar precision in the inference of angle. It is generally held that these calculations of angle are probably accurate only with 5° to 7° (Bevel and Gardner 1997).

We can evaluate a given bloodstain using a protractor, ruler, and calculator. After dividing the width of the stain by its length we always arrive at a number less than one. Using a bloodstain measuring 15 mm by 8 mm, for example, we get the sine of 0.5333. By then engaging the inverse sine function of the scientific calculator, we convert the sine to 32 degrees of angle. In place of a calculator, the investigator may make a table converting the sine to degrees. Such sine tables may be found in math reference materials.

After computing the angle, the investigator can place a protractor running lengthwise beside the bloodstain and better establish, in 3-dimensioinal space, the point of droplet origin. This is accomplished by running a string placed at the stain and stretched at the angle indicated by the protractor back toward the direction in which the bloodstain most probably came.

After taping strings beside several droplets and stretching the strands back toward the source, the point of convergence reveals the general point of origin. To illustrate, in

the case of a beating, the strings stretched from the bloodstains will intersect at the location where the victim endured the attack while the bloodletting occurred (Ristenblatt and Shaler 1995).

Computer Software

At least 2 computer software companies recently introduced forensic computer programs to replace the string method. One program now available employs actual flight path calculations which estimate droplet volume, gravity, and air resistance factors. Another program draws straight line paths for each bloodstain, then uses vector analysis to find the path of closest approach for each path.

Contamination Risks

Investigators working within bloodstain settings risk contamination from human immunodeficiency syndrome or HIV and hepatitis B. Both diseases are transmitted by contact with human body fluids.

Technicians investigating human injury or death within the crime scene setting may also be exposed to meningitis and tuberculosis. Game warden investigating crimes against wildlife face exposure to zoonotic diseases. Urban physicians do not routinely consider zoonosis or diseases that may be transmitted to humans in the diagnosis of febrile diseases. The wildlife officer must consider protection against rabies, rocky mountain spotted fever, plague, leptospirosis, tularemia, brucellosis, typhus, arbovirus, encephalitis, and spirochaetal relapsing fever.

For these reasons, analysts should adhere to simple precautions for protection from most communicable diseases. While within the investigatory area of concern, technicians are wise to wear eye protection, face masks, disposable protective clothing, and rubber gloves.

All collected evidence must be safeguarded to prevent contamination. After completion of evidence gathering, the investigator should, with a strong disinfectant, decontaminate all equipment exposed to blood or other body fluids. Before returning to other duties, the officer must also wash the hands with an antibacterial liquid (Geberth 1996).

Conclusion

Scientists have conducted various tests to compare human blood to that of animals. Even though mixed with anticoagulant, the blood of various species of animals, while stored in a tube, settles and the cells separate from the plasma. The blood of some species, like the horse, separates rapidly, while that of other species, like the cow, sheep, or goat seldom settles. Preserved blood in the vial may be remixed, but with gentleness to prevent rupture of the red cells (Schalm 1965).

Beginning in 1992 to 1998, this writer conducted limited tests comparing the stain patterns of animal blood to that of humans. Animal test subjects included

horses, cattle, and white-tailed deer. All blood samples had been preserved with EDTA and the age of the tested samples ranged from .5 hour to 8 days.

Experiments were performed with fresh blood, refrigerated blood vials and vials stored at room temperature. Before conducting bloodstain pattern comparisons all samples were gently agitated and allowed to reach ambient temperature. In order to study the patterns of the stains experiments included—but were not limited to—dripping equal volumes of blood onto angled targets, slinging blood from metal rods to targets, stomping into puddled blood, and shooting into bloody sponges, catching the dispersed spray on targets, etc.

All resultant animal bloodstain patterns were compared to those stains produced by human blood by measuring stain diameter, also by ascertaining length to width ratios, and by comparing the outline shape of animal bloodstains to those derived from a human. I found all bloodstains to be remarkably replicated regardless of source. By comparison, I found no pivotal dissimilarity in the geometric stain patterns between human blood and the above mentioned animal blood samples. Remaining on the side of caution, I make no assumption that all species' blood in flight will react identically or that the resulting stain patterns will be identical.

Further, one must keep in mind that perhaps an equal volume of blood from the selfsame tube specimen, when subjected to a series of identical tests, subtle distinctions—albeit minute—can be identified among bloodstains that first appear to be exact counterparts.

This preliminary research in bloodstain pattern interpretation has sprung from human death investigation. Based upon my experiments, these corresponding general principles of bloodstain pattern analysis may be employed successfully to investigate bloodstains at the scene of a crime not only against humans, but against wildlife and domestic animals as well.

No single approach to crime scene investigation many be considered superior to other means. James et al. (1998) noted, ". . . bloodstain pattern analysis is merely a forensic tool which may be used to better understand what may or may not have occurred during a bloodletting event."

Wildlife officers skilled in bloodstain pattern analysis will be able to use this to determine the sequence of events taking place in a hunting accident or incident and will also become more adept at investigating wildlife violations.

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