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A comparative study on variation in bloodstain patterns due to change in surface-using blood from four common animal species

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Abstract
Bloodstain pattern analysis is the collection, categorisation and interpretation of the shape and distribution of bloodstains associated with heinous crimes involving bloodshed such as homicide and suicide. The interpretation of the information is aimed at supporting inferences relating to actions that took place during an event involving blood and corroborating witness's statements, and identifying the participants. Bloodstain pattern analysis involves the application of scientific techniques to reconstruct events that resulted in a bloodstain pattern. Blood spatter patterns, at the scene of a violent crime can indicate how the crime occurred. The shape of spots of blood can provide information which may be helpful in reconstruction of sequence of events. In the present study the blood of four common animal species-human (*Homo sapien sapiens*), pig (*sus scrofa domestica*), goat (*Capra ibex*) and chicken (*Gallus gallus*) was allowed to fall from a fixed height of 14 inches on different horizontal surfaces. Twelve surface were chosen for the present study which included cardboard, cotton cloth, glass, metal, polished shoe, skin, thermocol, thin paper, thick smooth paper, wood, white tile and floor. The interspecies variation in shape and diameter of bloodstain pattern was studied.

Keywords: Interspecies variation, blood spatter, bloodstain pattern, reconstruction

1. Introduction
With any crime involving bloodshed there is possibility of resultant bloodstains in terms of both whom such stains could have come from and much staining could have been caused. Bloodstain pattern analysis involves the examination of size, shape and distribution of bloodstains at scenes involving bloodshed. A bloodstain pattern is a physical, geometric image created when blood leaves the body and strikes a surface. The following groups of patterns can essentially be distinguished: dripped and splashed blood, projected blood, impact patterns, cast-off stains, expirated and transferred bloodstains.

Blood is a liquid and has all the properties of a fluid. Because of surface tension the blood droplet assumes a spherical shape when it leaves the body. The surface tension protects the droplet from rupture until it impacts on a surface. Viscosity and cohesion between cells also play their part in how blood behaves outside the body. In 1ml of blood there are around 4.5 million red blood cells and 7,000 white blood cells in a healthy individual. If the cells are removed from the blood the resulting fluid is called plasma (Adrain and Adrain, 2009) [1].

When subjected to external forces the blood it behaves differently from water due to its constituents and it behaves like a non Newtonian fluid (Adrain and Adrain, 2009) [1]. Depending upon the gravity of the external forces the blood stains have been categorized into three groups.

a. Low velocity impact- the blood drops are formed by force of gravity alone. It includes free falling drops of blood, blood dripping into blood etc.
b. Medium velocity impact- the stains are formed by forces greater than gravity. The external force applied ranges between 5 and 25 feet/second. It includes beating with fists, hammer etc which causes blunt force trauma and cutting and stabbing trauma.
c. High velocity impact- the external forces are more than 100feet/second. It includes gunshot injuries, explosions etc. (James, 1998) [2-3].

Blood dropping vertically onto a flat surface will create a circular stain, suggesting its source was stationary at the time. Blood falling directly into a pre-existing blood stain will cause further drip patterns around the stain which are also known as satellite stains. A moving source such as a bleeding person while walking may drop blood onto a flat surface will create elongated stains in the shape of an exclamation mark. The shape of these droplets can often yield information regarding the direction and speed of the source. Larger droplets suggest the blood was travelling at a low velocity, whereas small droplets indicate the blood was travelling through air following a high velocity impact (James and Sutton, 1998) [2-3].

The analysis of bloodstain patterns may give information regarding distance from the target, impact angle and direction of travel, nature of external forces and object used to cause bloodshed and interpretation of multiple bloodshed events. The aim of the bloodstain pattern analyst is to recognise this basic nature of the stain through these physical characteristics, classify the pattern and then to associate the pattern back to a source event within the context of the scene. This helps to associate the pattern to a specific event that occurred during the incident in question (Bevel and Gardner, website)

The research in field of bloodstain pattern analysis goes back to several hundred years. The earliest study in the field was done by Pitrowski who after being called to a scene of homicide attempted to determine how bloodstains have been produced. Effect of surface texture as well as the effect of angle of impact on to the blood stain patterns follows the original work of Balthazard and his associates' subsequent significant work involving crime scenes was documented by Paul. Paul Kirk presented his findings in an affidavit concerning the bloodstain evidence in the highly publicized murder case against Dr. Samuel Sheppard in 1955. MacDonell (1971-1982) [8-11] also studied the effects of impact angle and surface texture on blood stain patterns. James and Sutton (1998) [2-3] also explain the effect of surfaces and impact angle on bloodstain patterns through the photographs. Bevel and Gardner (1997) [12], explains the effect of these factors on the bloodstain patterns. Hulse Smith and Illes (2005) [13] studied the stain diameter and counted the number of spines radiating out from the stains formed on paper, dry wall and wood. The bloodstains on different surfaces such as matt, vinyl silk and gloss painted surface following perpendicular and non perpendicular impact has also been studied (Adam, 2013) [14]. Very little research work in bloodstain pattern analysis is done in India.

In the present investigation the blood stains formed at low velocity impact have been studied. The blood samples of four animal species- Human (*Homo sapien sapiens),* pig (*Sus scrofa domestica),* goat (*Capra ibex)* and chicken (*Gallus gallus*) were collected and used for the analysis of bloodstain pattern formed under similar conditions. Red ink was used as control in the experiment. The blood stains formed on different surfaces was studied and diameter of the stains were recorded and analysed.

2. Materials and Methods

2.1 Sample Collection

The blood samples of four common animal species i.e. pig (*Sus scrofa domestica*), goat (*Capra ibex*) and chicken (*Gallus gallus*) were collected, labeled and packed from various butcher shops in Patiala city, Punjab, India. The Human (*Homo sapien sapiens)* blood was collected from the blood bank of Deep Hospital opposite to Punjabi University, Patiala. Blood samples were collected in 100 ml clean plastic vials using EDTA as anticoagulant and were used for the practical purpose almost immediately.

2.2 Experimental Design

A pointed knife was clamped with stand at a distance of 14 inches from the base of the stand. A drop of blood of these animal species and red ink was allowed to fall freely at an angle of 90°, on different surfaces such as white tile, cotton cloth, cardboard, thin paper, glass, thick smooth paper, smooth finished wood, floor, polished shoe, skin, smooth metal surface and thermocol. The variation in blood stain pattern on different surface was studied. The diameter of blood stains was also recorded.

2.3 Photographic Documentation

The photographs of blood stain pattern was also taken using canon power shot A 430 camera (4 mega pixels resolution) on macro mode, with scale.

3. Results and Discussions

The shape of blood stains patterns formed by blood of different animal species and red ink at an angle of 90° is studied. When blood is allowed to fall freely from the fixed height of 14 inches there is variation in blood stain patterns. Different types of blood stain patterns are seen when the drop of blood strikes the surface. The shape of blood stain depends upon the nature of surface. The porus surface causes the drop to rupture as the forces of surface tension are overcome on impact. Distortions of blood stains are seen in form of spines which radiate from the central area of the blood stain. Spines are formed in the process of overcoming the surface tensions which holds the drop together. Satellite spatters are also seen which are formed when the blood falls from a stationary source and on a horizontal surface. Spatters are also seen around the periphery of the blood stain. Similarly the structure and composition of the fabric of the garment will influence the appearance of any bloodstain on that garment as it does not have a smooth surface and results in distortions of the stain. On hard smooth surface there are least distortions in the shape of bloodstains.

Figure I shows the stain patterns formed by the red ink on different surfaces such as cardboard, cotton cloth, glass, metal, polished shoe, skin, thermocol, thin paper, thick smooth paper, wood, white tile and floor. Cardboard, thin paper, thick smooth paper, wood, white tile and floor shows circular stain patterns with spines. Floor also shows formation of satellite droplets. Glass surface shows complete circular stain pattern without spines. Cotton, Polished shoe, skin and thermocol shows irregular stain pattern formation with cotton showing formation of satellite droplets and thermocol showing spines. Metal surface shows formation of incomplete circular stain pattern with evenly-spaced small spines.

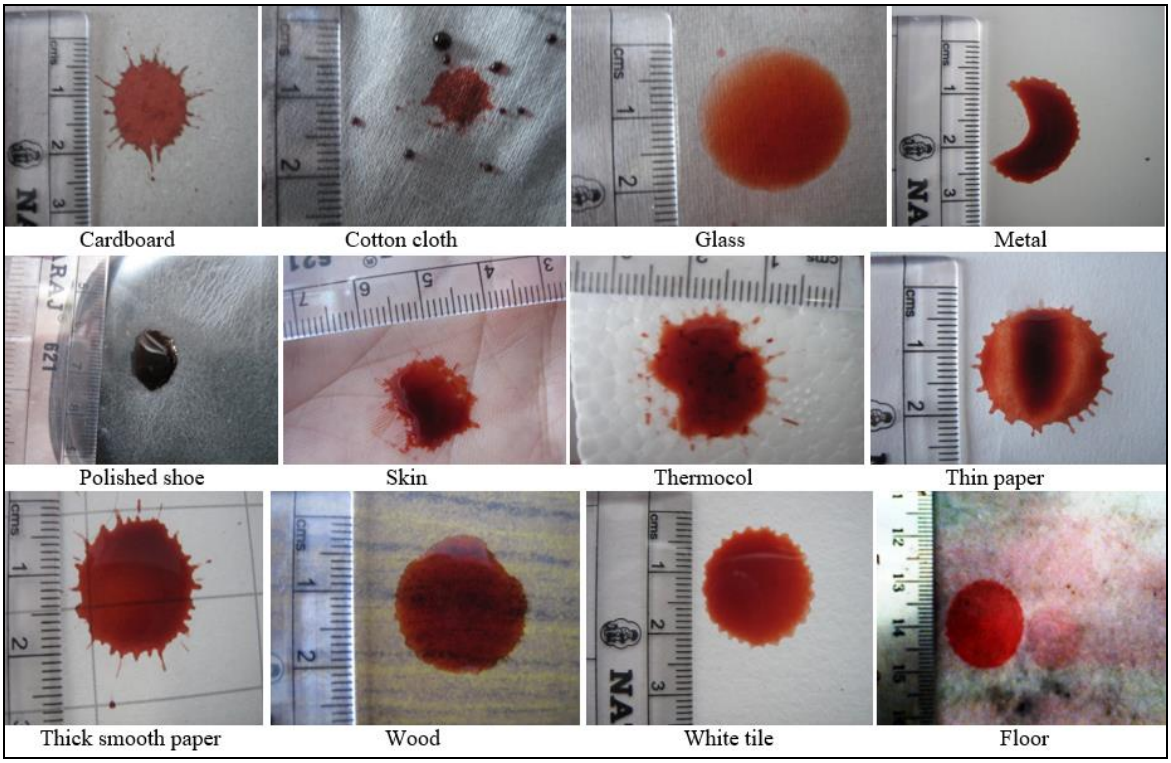

Fig 1: Red ink stain patterns on different surfaces

Figure 2 shows the stain patterns formed by human blood on various surfaces. On cardboard very few spines are seen around the stain. On cotton cloth and thermocol satellite patterns are seen with distortions in the stain pattern. On glass, metal, wood, white tile circular stains are seen and on polished shoe small spines are formed around the periphery of the stain. On thin paper regularly spaced small spines are seen and on floor maximum satellite droplets are formed with regularly spaced spines.

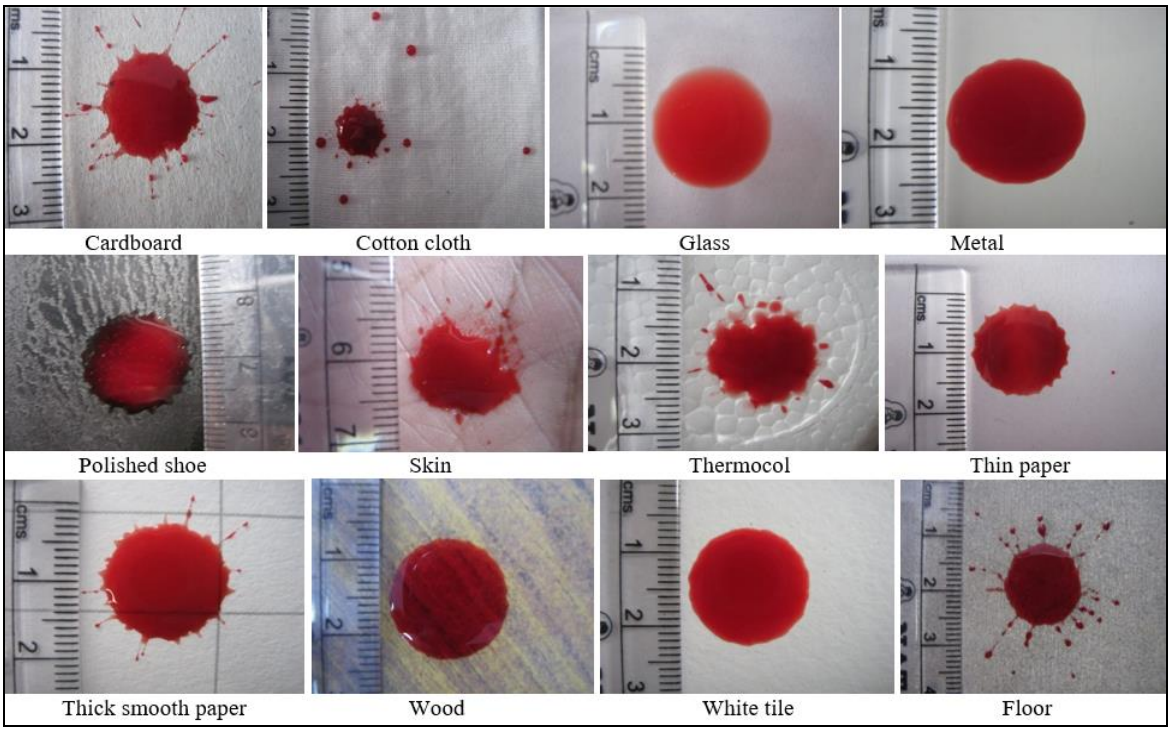

Fig 2: Blood stain patterns formed by human blood on different surfaces

Figure 3 shows the bloodstain patterns formed by the pig (*Sus scrofa domestica*) on various hard and smooth surfaces. On cardboard, thermocol, thick smooth paper and cotton cloth satellite droplets are seen, on glass circular stain is formed; on metal and skin distorted stain is formed. Thin paper and floor shows circular stain pattern with evenly spaced small spines. Stain with wavy margins is seen on white tile and wood.

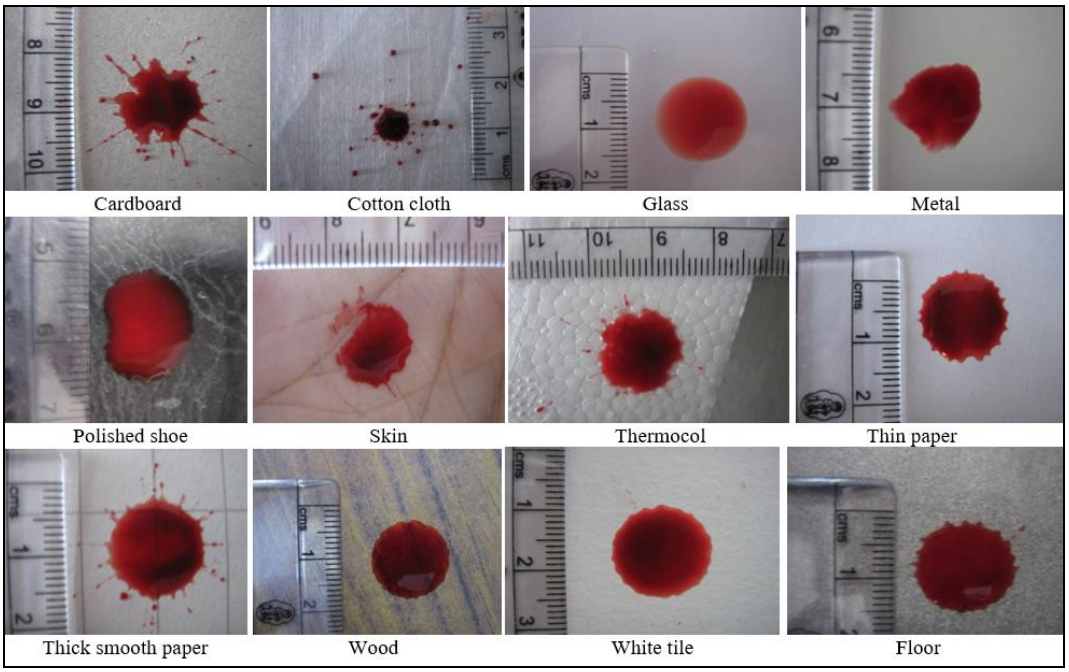

Fig 3: Blood stain pattern on different surfaces by pig blood

Figure 4 shows the effect of different surfaces on blood stain patterns formed by goat blood. On white tile, metal, wood and glass circular stain pattern is formed. Thick smooth paper and cardboard shows circular stain pattern with maximum spines and little satellite droplets. Cotton cloth and floor shows circular stain pattern with satellite droplets. Circular stain patterns with evenly spaced small spines are formed on thermocol and thin paper. Irregular stain pattern is formed on skin and polished shoe.

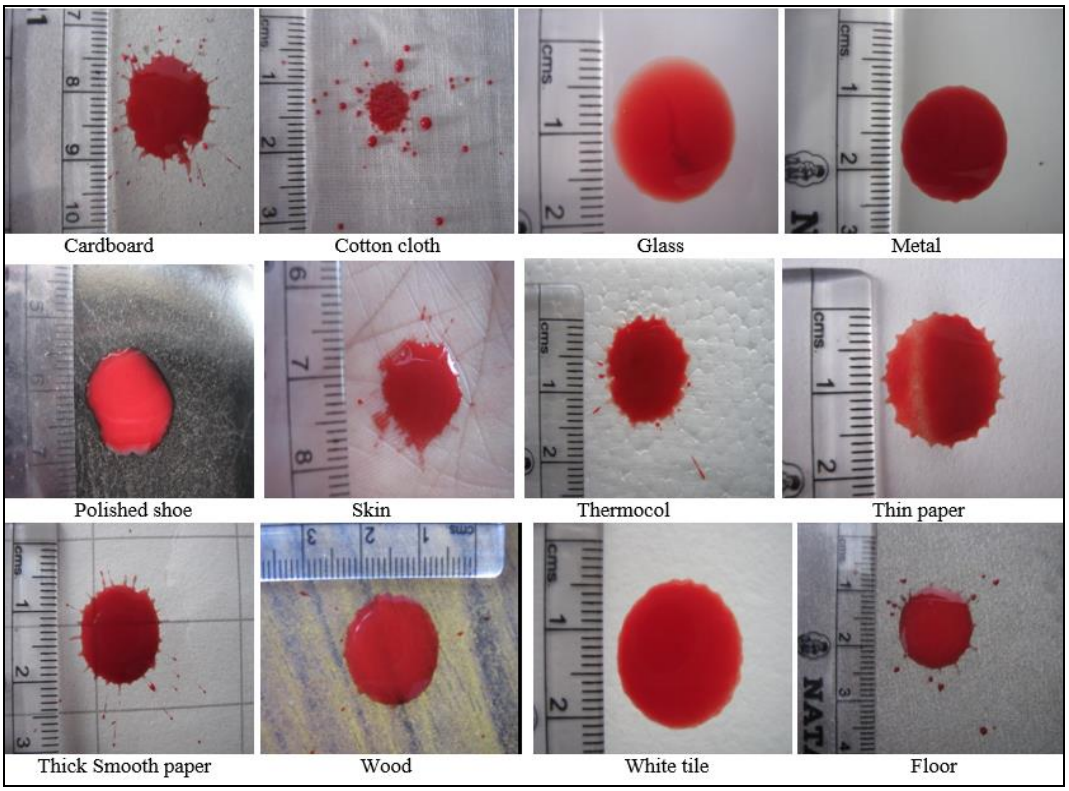

Fig 4: Variation in blood stain patterns on different surfaces by goat blood.

Figure 5 shows the blood stain patterns formed by chicken's blood on various porous and non porous surfaces. Blood stains on cardboard and thick smooth paper shows circular stain patterns with long spines and little satellite droplets. Polished shoe, skin and thermocol shows irregular stain patterns. Wood, white tile, glass,thin paper and metal shows circular stain patterns with wood and thin paper showing small evenly spaced spines. Floor shows small satellite droplets and cotton cloth shows few satellite droplets around the periphery of the central stain.

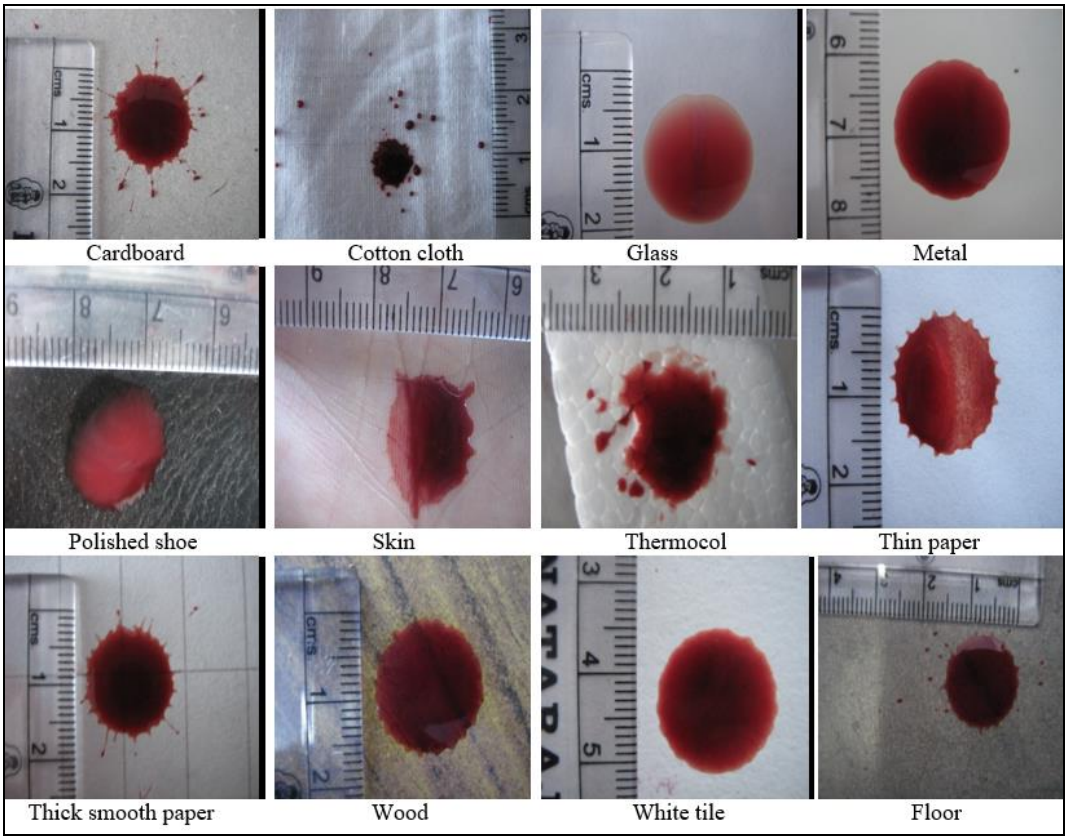

Fig 5: Bloodstain patterns formed by chicken blood on different surfaces.

Table 1 shows the variations in the patterns formed by the blood of above four animal species and ink control on twelve different surfaces (white tile, cotton fabric, cardboard, thin paper, glass, thick smooth paper, finished wood, floor, polished shoe, skin, smooth metal surface and thermocol). In this variations in the patterns have been observed in the form of shape, presence of spines, satellite droplets and margins.

Table 1: Shows the variations in the patterns formed by the blood of four animal species and ink control on twelve different surfaces

	Surfaces	Ink control	Human blood	Pig blood	Goat blood	Chicken blood
1.	White tile	Circular, wavy margins	Circular	Circular	Circular	Circular, wavy margins
2.	Cotton	Irregular, satellite droplets	Irregular, satellite droplets	Irregular, satellite droplets	Irregular, more satellite droplets	Irregular, more satellite droplets
3.	Cardboard	Circular, spiny margins	Circular, spiny margins	Irregular	Circular, spiny, satellite droplets	Circular, spiny margins
4.	Thin paper	Circular, pointed margins	Circular, pointed margins	Circular, pointed margins	Circular, pointed margins	Circular, pointed margins
5.	Glass	Circular	Circular	Circular	Circular	Circular
6.	Thick smooth paper	Circular, spiny	Circular, spiny	Circular, spiny, satellite droplets	Circular, satellite droplets	Circular, spiny margins
7.	Smooth finished wood	Circular, wavy margins	Circular	Circular	Circular, satellite droplets	Circular, wavy margins
8.	Floor	Circular with spines	Circular, satellite droplets	Circular, spiny	Circular, less satellite droplets	Circular, satellite droplets
9.	Polished shoe	Irregular	Irregular	Irregular	Irregular	Irregular
10.	Skin	Irregular	Irregular	Irregular	Irregular	Irregular
11.	Smooth metal surface	Incomplete circle with spines	Circular	Irregular	Circular	Circular
12.	Thermocol	Irregular	Irregular	Irregular	Circular. Satellite droplets	Irregular

Table 2 shows the variation in diameter of the stain patterns formed by different animal species and by ink control on six different smooth surfaces. Maximum similarity have been observed in the diameter of patterns formed by human and pig blood.

Table 2: Variation in diameter of the stain pattern on different surfaces

	Blood	Thin paper	Thick paper	White tile	Finished wood	Cardboard	Floor
1.	Ink control	18	16	19	17	15	18
2.	Human	14	16	16	16	14	14
3.	Pig	14	15	16	15	14	14
4.	Goat	15	15	17	16	16	15
5.	Chicken	16	15	16	15	15	15

Variations have been observed in the shape and diameters of bloodstain patterns in all species as well as in pattern obtained by ink sample, where blood from selected animal species was made to fall from a fixed height of fourteen inches at 90°. Red colour ink was used as control sample. The blood stains formed by low velocity impact have been studied. These types of stains are formed when the blood falls freely under the influence of gravity (James and Sutton, 1998) [2-3]. In a perpendicular collision, a round stain is observed. The shape and diameter of stains produced is dependent on the texture of the surface. The variation in blood stain patterns on different surface are studied which are commonly encountered at crime scenes. The angle at which the blood droplet impacts an object and the nature of that surface determine the final shape of the stains (Sweet, 2006) [15].

Patterns formed on 12 commonly found surfaces (white tile, cotton fabric, cardboard, thin paper (smooth), glass, thick smooth paper, finished wood, floor, polished shoe, skin, smooth metal surface, thermocol) vary with respect to margins of spherical pattern i.e. wavy or spiny, shape i.e. circular or irregular and number of satellite droplets formed. On white tile circular stains are formed by all species of animals as well as by red ink. Cotton cloth shows irregular stains with satellite drops formed by red ink ink, human and pig blood whereas more satellite drops are formed by goat blood and chicken blood. The distortion will depend on the ability of the fabric to absorb the bloodstains and the looseness of the weave, knit or felt of the garment material. Consequently, the composition and construction of the clothing of any bloodstained garment must be considered in the evaluation of any blood stain pattern (DiMeo and Taupin, 2012) [16]. Circular stains with spiny margins are formed on cardboard by blood of all species and red ink except pig blood which forms irregular stains. On thin paper circular stains with pointed margins are formed and on glass completely circular stains are formed by control i.e. red ink and blood of all the animal species. Thick smooth paper shows circular and spiny stains by red ink, human and chicken blood whereas in addition to spines satellite drops are also formed by pig and goat blood. Red ink and chicken blood forms circular stains with wavy margins on smooth finished wood, circular stains are formed by human and pig blood and goat blood forms satellite drops also around the periphery of the stain. On floor circular stains with satellite drops are formed by red ink, human, goat and chicken blood whereas circular stains with spines are formed by pig blood on similar surface. Polished shoe and skin show irregular pattern for blood of all above four animal species as well as ink control. Smooth metal surface shows irregular stains by red ink and blood of pig whereas circular stains are formed by human, goat and chicken blood. On thermocol irregular stains are formed by red ink and all species of animals except goat blood which shows circular stain with satellite drops.

3.1 Explain Table 2

Spines around the edges of stains in Figs. 3 and 4 were not evenly distributed and showed variation in size. Local variations in surface roughness of the paper were responsible for introducing some randomness in the size of spines and also led to some merging of spines. Stain size increased as surface roughness was reduced, so that the largest stains were on glass and the smallest on paper.

Therefore, consideration of surface texture is a key observation when determining the characteristics of the blood spatter (Fisher and Spitz, 2006) [17]. The surface that blood hits can change the shape and size of a spatter significantly. Hard and smooth surfaces will tend to create a spatter pattern that is much smaller than the rough or irregular shaped surfaces like wood or concrete. Secondary or satellite spatter is often created when a drop falls to a hard surface. These small secondary drops will surround the original circular stain.

Bloodstains may occur on a crime scene on a variety of surfaces such as carpet wood, tile wallpaper, clothing etc. The type of surface that a blood droplet strikes affects the amount of resultant stain distortion and satellite (secondary) blood spatter. When a drop of blood hits a hard or non-porous surface, such as glass or smooth tile squares, it results in fewer spatters. If the drop hits a rougher surface such as carpet or wood, it will usually result in an irregular shaped stain that has serrated edges and has satellite spatter around it (Saferstein, 2001) [18]. If the blood drop happens to land on a porous surface, like raw wood or asbestos board for example, there will be fewer spatters produced. This may contrast with the blood drop falling on a paper towel whose surface is both porous and rough in texture. Interspecies variation in shape of bloodstains on twelve different horizontal confirms that pig blood drops behave very much like those of human blood. Similar observations have been made by (Hulse Smith *et al*., 2005) [13].

Most bloodstain pattern analysis is typically undertaken while examining scenes of violent crime, or examining clothing and weapons from such incidents. A crime scene investigation is also about finding evidence to identify the culprit of the crime. Bloodstain pattern analysis can contribute to this, in addition to investigations for traces such as fingerprints, fibres or DNA.

In bloodstain pattern analysis it is important to know the effect of different surfaces on shape and size of the bloodstain. Spreading of small liquid drops over thin dry porous layers is investigated from both theoretical and experimental points of view by different workers. Drop motion over a porous layer is caused by an interplay of two processes: (a) the spreading of the drop over already saturated parts of the porous layer, which results in an expanding of the drop base; (b) the imbibition of the liquid from the drop into the porous substrate, which results in a shrinkage of the drop base and an expanding of the wetted region inside the porous layer. As a result of these two

competing processes, the radius of the drop goes through a maximum value over time (Starov, 2005).

The study of blood stain patterns on different surface helps in the reconstruction of scene of crime as was seen in case of Countess Alberica Filo della Torre was found dead in her home in Rome in 1991. She had a large bloodstained bed sheet wrapped around her neck. The position of the bloodstains confirmed the reconstruction of the way the bed sheet had been wrapped around her neck (Berti and Saachi, 1991)

Blood from Pig (*Sus scrofa domestica*) is mainly used for the practical purposes in studying bloodstain patterns since its specific gravity being closer to the specific gravity of human blood (Bevel and Gardner, 1997) [12]. To the best of our information there is no literature available which shows the use of blood from other two animal species i.e., Chicken (*Gallus gallus*) and Goat (*Capra ibex*) for the study of bloodstain patterns and comparison of the blood stain patterns formed by the blood of above species with that of human and pig blood.

A highly qualified analysis can help to estimate facts concerning the location, quality and intensity of an external force. A sequence of events may be recognized, and detailed questions connected with the reconstruction of the crime might be answered. In some cases, bloodstain pattern analysis helps to distinguish between accident, homicide and suicide or to identify bloodstains originating from a perpetrator. Bloodstain pattern analysis is based on systematic training, a visit to the crime scene or alternatively good photographic documentation, and an understanding and knowledge of autopsy findings or statements made by the perpetrator and/or victim (Peschel *et al*., 2011) [22].

This study shows that the way in which bloodstains form on a surface is unique for that particular surface. It is therefore important for forensic analysts to be aware that the surface upon which an impact pattern is formed can affect the interpretation of facts. Since blood evidence associated with a crime can provide information that may solve the case hence much research is required in the field in India.

4. Summary and Conclusion

Investigators often find blood stains during their examination of a crime scene. They also find stains that could be either blood or some other similar substance, like reddish-brown paint or it may be blood of some other animal species.

This study shows there are variations in blood stain patterns formed by different species of animals with respect to shape and diameter of the satin. The surfaces on which the bloodstains are found are important in the assessment of bloodstains. Bloodstains on rough/textured surfaces were longer than those on smooth/non-textured surfaces, even though the volume of the blood drop was the same in each situation. This indicates that the way in which blood interacts with these different surfaces is different. Surface texture can play a vital role in the study of blood stain pattern analysis.

Blood stain pattern analysis provides important information to the investigators regarding the crime scene reconstruction hence the present study may be helpful in forensic investigation of heinous crimes involving bloodshed.

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