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AN EXPERIMENTAL ANALYSIS OF BLOOD IN FORENSIC SCIENCE: BLOOD STAIN PATTERN

¹Ms. Vijeta S Alavani, ²Mr. Vinayak Nidasoshi, ³Mr. Sai Krishna A

PG- Student Department of Criminology and Forensic Science Rani Channamma University,
Belagavi Belgavi-591156, Karnataka Contact No: 6364321913
Email: vijetaalavani32@gmail.com / vinayaknid93@gmail.com

Research Scholar Department of Criminology and Criminal Justice Rani Channamma University,
Belagavi Belgavi-591156, Karnataka Contact No: 9901636776
Email: vinayaknid93@gmail.com

Research Scholar Department of Criminology and Criminal Justice Manonmaniam Sundaranar
University Tirunelveli, Tamilnadu Contact No: 7449113698 Email:
saikrishna06031998@gmail.com

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[doi: 10.48047/AFJBS.4.4.2022.396-425](https://doi.org/10.48047/AFJBS.4.4.2022.396-425)**ABSTRACT**

Objectives: The blood stain patterns are the most valued evidence in the court of law which we collected in the scene of crime, as part of this context the Blood is much authenticated Biological(Serological) evidences in the field of Forensic Science. With the help of blood stains we trace the Culprit /Suspect and in the finding of scientific reason and also causation behind the actions done by Perpetrator. As this work intended to explore the various typologies of blood stains and measurement of the blood stains patterns which are presented in different types of surfaces (under Controlled medium). **Methodology:** for fulfillment of the criteria getting result, the researcher has been taken an Experimental research design; it involves controlled experiments where various factors are manipulated to create blood spatter patterns. With Controlled experiment design where Blood spatter measurement was conducted in a controlled environment to minimize external variables. A clean and well-ventilated laboratory space was used for all experiments. Sample of the Study(To get intended result researcher opted animal (Goat) blood to used as a samples for this study (Approximately 50 ml) because both goat and Homo sapiens have same in the Blood coagulation(Blood Clotting factor) values. **Findings:** paper has been Evaluated the origin pint of Dropped blood in the scene of crime (Simulated Crime scene) with this the researcher found the Angle of Impact (Length and width) of the blood stain patterns differ from the surface to surface. Researcher analyzing, Computing and to determine origin and Direction of the Bloodstain pattern. **Novelty:** This study signify the Dropped point and Origin & Direction point of Blood stains with this scientific information IO may can Inculcating further Investigation by using this scenario and in the reconstruction of Scene of Crime as part in the Investigation.

KEY WORDS: Blood Pattern Analysis, Serology, Angle of Impact, Dropping point.

INTRODUCTION

Blood is a specialized body fluid. It has four main *components* i.e. Red blood cells, white blood cells, platelets, plasma. With this Blood have many different functions, including, transporting oxygen and nutrients to the lungs & tissues. The study of blood is known as **hematology**.

Blood Spatter/ Patterns Analysis (BPA) is the technique that can be helpful in determining if a crime was committed and if the blood is evidence in that crime. Bloodstain pattern analysis is the Interpretation of blood at a crime scene In order to reconstruct crime scene of actions that caused the bloodshed. BPA is the one of interpretation method where we analyze bloodstains which are present in a crime scene and in order to recreate the actions that caused the bloodshed. Experts examine the size, shape, distribution and location of the bloodstains to form opinions about what did or did not happen, and using principles of biology (behavior of blood), physics (cohesion, capillary action and velocity) and mathematics (geometry, distance, and angle) these all applications are assist to investigators in answering suspicious questions pertaining to a specific incidents such as:

- From where blood comes?
- What caused the wounds?

- From what direction was the victim wounded?
- How were the victim(s) and perpetrator(s) positioned?
- What movements were made after the bloodshed?
- How many potential perpetrators were present?
- Does the bloodstain evidence support or refute witness statements?

In the context of forensic science, it is highly significant to study blood spatter. It helps us understand what happened at crime scenes and how violent events unfolded. The specific patterns created when blood droplets fall on different surfaces provide investigators with important information about how these events happened. In this way, police and forensic experts have a powerful tool that helps them put together a detailed timeline of what happened in a chaotic situation.

The main goal of this detailed investigation is to improve our understanding of blood spatter analysis and how it can be used in forensic examinations. The diverse field of forensic science is a complex puzzle made up of many pieces of specialized knowledge. Each piece is important and helps us solve crimes. Blood spatter analysis is important and plays a big role in understanding how blood moves and splatters. It's like an art display that shows how blood behaves, and it's really meaningful in the bigger picture. As little drops of blood land on things, they leave a mark that tells stories about how they moved and hit. These stories can change how people understand how humans interact. The authentic significance of blood spatter analysis is observed through the captivating interplay of minuscule and grand aspects. In the difficult task of figuring out what happened at a crime scene, investigators and experts have to put together small pieces of evidence to find the bigger truth. Blood spatter analysis helps shed light on confusing parts, so it's like a guiding light in this field. By figuring out the mysterious designs made with blood, the investigator discovers a map that shows the movements and actions that formed the scene in front of them. The marks left by a hard hit, the path of something flying through the air, the speed of a collision—all are written on the pattern of small drops, waiting for someone observant enough to understand what they mean. The core of this research lies in the bold choice to use goat blood, which is a humble yet very important substitute, to imitate how human blood works. This text is about studying similarities between different species. The researcher has thought carefully about these similarities and is interested in exploring them further.

The findings of this research have highly significant and wide-ranging effects. Outside of explaining theories, there is a real effect on forensic investigations. The use of goat blood instead of human blood for creating patterns of blood spatters at crime scenes can improve the accuracy and trustworthiness of crime scene reconstructions. Law enforcement agencies are trying to

understand messages written in blood, and now they have a better understanding and are more aware of how to do it because of this study. Using goat blood instead of something else helps in work and shows the connection between studying science and using it in the real world. Ultimately, this study highlights the unceasing thirst for knowledge that fuels scientific investigation. The study of blood spatter is a mix of art and science. It requires investigation and intuition to understand the patterns of drops. We are encouraged to explore and find meaning in this intricate dance of blood droplets. This research paper uses goat blood instead of human blood to learn new things about forensic science.

One of the pioneering figures in blood spatter analysis was Dr. Herbert MacDonell, an American forensic scientist. In the 1950s, he conducted extensive research and experimentation, establishing fundamental principles that laid the groundwork for modern bloodstain pattern analysis. MacDonell's work emphasized factors such as the angle of impact, the point of convergence, and the shape of bloodstains. During the latter half of the 20th century, advancements in technology, including high-speed photography and computer modeling, greatly enhanced the accuracy and reliability of blood spatter analysis. These tools allowed forensic experts to conduct more sophisticated experiments and simulations, leading to a deeper understanding of bloodstain dynamics.

In the 1970s, the International Association for Bloodstain Pattern Analysts (IABPA) was founded, further legitimizing blood spatter analysis as a recognized forensic science. The IABPA established guidelines and standards for practitioners, promoting consistency and professionalism in the field. Blood spatter analysis has played a pivotal role in countless criminal investigations, including homicide cases. It can help determine the sequence of events, the number of blows or shots, the position of the victim and assailant, and even the type of weapon used. However, it is important to note that while bloodstain pattern analysis can provide valuable evidence, it is just one piece of the forensic puzzle and should be used in conjunction with other forms of evidence and expert testimony.

Today, blood spatter analysis continues to evolve with ongoing research and technological advancements, contributing to the pursuit of justice and the accurate reconstruction of crime scenes. It remains a critical tool in forensic science, aiding investigators in unraveling the mysteries of violent crimes.

Background and significance:

Blood spatter analysis, also called bloodstain pattern analysis (BPA), is a complex part of forensic science that combines physics, biology, and math to carefully uncover the hidden stories told by bloodstains. The historical origins of this can be traced back to the early efforts of Dr. Paul Leland Kirk studied bloodstains and how they behave and are understood during the 1930s. This was a time when people were gaining a lot of important information about bloodstains. Over time, the study of blood spatter has changed a lot and become a very important tool for forensic investigators. It helps them understand crime scenes, recreate events, and either support or question what witnesses say. Understanding blood spatter patterns involves many details, like how fast and which way the drops of blood hit surfaces, the angles they land at, the texture of those surfaces, and even the thickness of the blood itself. It's like a complex dance with many factors at play. A mix of many things come together and works well, turning normal splatters into a detailed and meaningful story of possibly violent meetings. As time goes by, forensic experts are discovering more about how blood spatter can give clues in solving crimes. They are using more advanced methods to analyze the patterns and uncover important information from bloodstains.

Theory and underlying principles of bloodstain pattern analysis:

Bloodstain pattern analysis (BPA) is a fundamental discipline within forensic science, providing critical insights into the dynamics of crime scenes and shedding light on the events that transpired. At its core, BPA relies on the principle that blood, though a complex fluid, behaves in a predictable manner when subjected to various internal and external forces. This predictability forms the basis for evaluating bloodstain patterns and deciphering the narrative of a violent incident. The essence of BPA lies in understanding how blood, as a fluid, responds to different forces and mechanisms. This knowledge is garnered through controlled experiments, where known patterns are meticulously created under specific conditions. These known patterns serve as reference points for the bloodstain pattern analyst when they encounter unknown patterns at crime scenes. By comparing the unknown stains to these known patterns, analysts can draw important conclusions.

One of the cornerstones of BPA is the general predictability of blood's behavior under controlled conditions. This predictability allows analysts to categorize bloodstains based on class characteristics, which include factors like the size, shape, and distribution of the stains. Class characteristics provide a foundation for understanding the basic properties of the bloodstains encountered, and they are crucial for drawing initial inferences during investigations. Beyond class

characteristics, BPA delves into more intricate aspects of bloodstain patterns. Three underlying principles guide the behavior of bloodstain pattern analysts;

1. The Pattern Diversity Principle:

The Pattern Diversity Principle is a fundamental concept in forensic science, particularly in disciplines like bloodstain pattern analysis and crime scene reconstruction. This principle emphasizes the idea that a variety of factors and conditions can lead to the creation of different patterns in bloodstains or other physical evidence found at a crime scene. Understanding and acknowledging this diversity of patterns is crucial for accurate and reliable forensic analysis. One of the key aspects of the Pattern Diversity Principle is that it recognizes the complexity of real-world situations. Crime scenes are dynamic and can involve multiple variables, including the type of force applied, the angle of impact, the surface characteristics, and the velocity of the blood. Each of these factors can contribute to the formation of unique patterns, making it essential for forensic analysts to consider a wide range of possibilities.

By embracing the Pattern Diversity Principle, forensic experts are better equipped to avoid tunnel vision and confirmation bias. They understand that there is no one-size-fits-all approach to interpreting bloodstain patterns or other evidence. Instead, they approach each case with an open mind, considering various hypotheses and scenarios that may explain the observed patterns. Moreover, the Pattern Diversity Principle underscores the importance of continuous research and experimentation in forensic science. It encourages forensic experts to conduct controlled experiments and studies to better understand the factors that influence pattern formation. This empirical approach helps build a body of knowledge that can be applied to realworld cases, improving the accuracy of forensic analyses.

In practice, the Pattern Diversity Principle is employed in various ways. Forensic analysts carefully document and analyze bloodstain patterns, taking into account all relevant variables and factors. They use mathematical models, physics, and biology to reconstruct the events leading to the formation of these patterns. By doing so, they can provide valuable insights into crime scene dynamics, which can assist law enforcement agencies in solving crimes and bringing perpetrators to justice. Pattern Diversity Principle is a cornerstone of forensic science that acknowledges the intricacies and variability of pattern formation in physical evidence. It guides forensic experts to approach their work with an open and scientific mindset, ensuring that their analyses are grounded in empirical evidence and capable of withstanding scrutiny in the pursuit of justice.

2. The Principle of Stain Shape and Vector Correlation:

The Principle of Stain Shape and Vector Correlation is a critical concept within the field of bloodstain pattern analysis, a vital component of forensic science. This principle underscores the importance of examining the shapes and vectors (directions) of bloodstains to gain valuable insights into the dynamics of a crime scene. By understanding the relationships between these elements, forensic experts can reconstruct events and assist in criminal investigations. The analysis of stain shape involves the examination of the physical characteristics of individual bloodstains. These characteristics include the size, outline, and internal features of the stains. For example, the shape of a bloodstain may be circular, elliptical, or irregular, and it may exhibit features such as satellite spatters or a central void. These attributes can provide clues about the angle of impact, the velocity of the blood, and the nature of the object or force that caused the bloodshed.

Vector correlation, on the other hand, focuses on the directionality of bloodstains. This involves determining the angle at which the blood droplets impacted the surface and the resulting direction of travel. By analyzing the vectors of multiple bloodstains within a pattern, forensic experts can establish the point of origin, or area of convergence, which helps in reconstructing the sequence of events leading to the bloodshed. The Principle of Stain Shape and Vector Correlation recognize that stain shape and vector analysis are interrelated. The shape of a bloodstain can offer insights into the direction of travel and the angle of impact, and vice versa. When these elements are combined, a more comprehensive understanding of the bloodstain pattern emerges.

In practical terms, forensic analysts meticulously document bloodstains, noting their shapes, sizes, and angles of impact. Advanced mathematical models and trigonometric calculations are often employed to analyze the vectors and determine the point of origin accurately. This information is then used to develop crime scene reconstructions, providing law enforcement agencies with valuable evidence to aid in solving crimes. The Principle of Stain Shape and Vector Correlation is an indispensable tool in forensic science, as it allows for a systematic and scientific approach to interpreting bloodstain patterns. By considering both stain shape and vector analysis, forensic experts can provide courts with evidence-based reconstructions of events, contributing to the pursuit of justice and ensuring that accurate conclusions are drawn from the evidence presented.

3. The Physically Altered Bloodstain (PAB) Principle:

The Physically Altered Bloodstain (PAB) Principle is a fundamental concept within the field of bloodstain pattern analysis, a crucial component of forensic science. This principle recognizes that bloodstains at a crime scene can undergo physical alterations, such as smudging, dilution, or

distortion, due to various factors and events. Understanding and accounting for these alterations is essential for accurate forensic analysis and the reconstruction of events. One of the key aspects of the PAB Principle is acknowledging the dynamic nature of crime scenes. Crime scenes are often chaotic, with multiple factors in play, including movement of people or objects, weather conditions, and the actions of first responders. These factors can lead to changes in the appearance and distribution of bloodstains, which forensic analysts must consider when interpreting the evidence.

The PAB Principle underscores the importance of distinguishing between primary and secondary bloodstains. Primary stains are those created directly from the source of the bloodshed, while secondary stains are those that have been subsequently altered due to external factors. Recognizing and differentiating between these two types of stains is crucial for understanding the sequence of events and establishing a reliable timeline. In practice, forensic experts carefully document the condition of bloodstains at the crime scene, noting any alterations or distortions. This documentation often involves the use of photography and detailed sketches. By assessing the extent and nature of physical alterations, analysts can make informed interpretations about the original patterns and events that occurred.

The PAB Principle also encourages the use of controlled experiments and studies to replicate and understand the effects of various physical alterations on bloodstains. These experiments can provide valuable insights into how factors like rain, movement, or contact with other surfaces can impact bloodstains and help forensic experts make accurate interpretations. In conclusion, the Physically Altered Bloodstain (PAB) Principle is a fundamental tenet of bloodstain pattern analysis, emphasizing the dynamic nature of crime scenes and the potential for bloodstains to undergo physical alterations. By recognizing and accounting for these alterations, forensic experts can provide accurate reconstructions of events and contribute to the pursuit of justice by presenting reliable evidence in court.

Bloodstain pattern analysis serves as a vital tool in forensic science, particularly in the investigation of violent crimes. While it cannot identify specific individuals involved in a crime, it can provide answers to a range of critical questions:

Origin of the Blood: BPA helps determine where the blood originated within a crime scene, shedding light on the location of the initial incident.

Cause of the Wounds: By analyzing the bloodstain patterns, analysts can infer the type and direction of force that caused the injuries leading to bloodshed.

Victim and Perpetrator Positions: BPA can reveal the positions of the victim and perpetrator(s) at the time of the bloodshed, offering insights into the dynamics of the incident.

Post-Bloodshed Movements: Bloodstain patterns can indicate any movements or actions taken by individuals after the bloodshed occurred, providing a timeline of events.

Number of Potential Perpetrators: In some cases, BPA can help determine the number of individuals present during the bloodshed event, which can be critical in investigations. In essence, bloodstain pattern analysis is a powerful forensic tool that assists investigators in reconstructing the sequence of events at crime scenes, allowing them to piece together a more comprehensive understanding of the circumstances surrounding violent incidents. While BPA may not identify culprits directly, it plays a pivotal role in the pursuit of justice by providing objective and scientific insights into the "what" and "how" of bloodshed events. The information imparted by blood patterns for reconstruction purposes include the following:

- ✓ Where did the blood come from?
- ✓ What caused the wounds?
- ✓ How were the victim and perpetrators position?
- ✓ What movements were made after the bloodshed?
- ✓ How many potential perpetrators were present?

Bloodstain Pattern: Bloodstain pattern is very important way to telling what happened at a crime scene based on the pattern of blood that could be on wall, floor that can be tells the story. There are mainly three types

1. Passive blood stain pattern
2. Transfer bloodstain pattern
3. Projected bloodstain pattern

1) **Passive blood stain pattern:** passive blood stains usually blood drips directly onto a surface with no force applied to it. Further classified into three different types i.e.

- a. **Droplets:** It's just circular drops that vary depending on surface. Surface smooth we will have a well drop, if we drop on the rough surface the blood drops will contains satellites and spikes.
- b. **Pools:** Victim remains in one place while bleeding heavily. Usually know that the victim was where fall concern amount of times that much blood

- c. **Trails:** These are usually spots left by the victim as they move from one place to another. Final leaving it and someone to follow to show where the victim went and absolutely how long it.
- 2) **Transfer bloodstain pattern:** A transfer bloodstain is created when a wet, bloody surface comes in contact with a secondary surface. A recognizable image of all or a portion of the original surface may be observed in the pattern. further classified into two types
- a. **Swipe** bloodstain pattern: the transfer of blood onto a clean surface.
- b. **Wipe** bloodstain pattern: when an object moves through wet blood and moves, removes or alters it.
- 3) **Projected bloodstain pattern:** When blood is sent in a direction. The tail of the droplet indicates the direction of travel. These occur by the blood that travelled in the air. Impact stains occur by when a force is applied to the source of blood and there are three types in this bloodstain pattern namely, high impact velocity, medium impact velocity and low impact velocity blood stain pattern.
- a. **Angle of impact:** The angle of impact in bloodstain pattern analysis is a crucial aspect that provides valuable insights into the dynamics of a crime scene. It reveals the angle at which blood droplets struck a surface, which can be instrumental in reconstructing events. Determining this angle involves a meticulous process. To calculate the angle of impact accurately, forensic experts must consider the width and length measurements of the bloodstain. However, they deliberately exclude the measurement of the tail. This omission is essential because the tail is primarily influenced by two significant forces: gravity and the force applied by the weapon or object. By excluding the tail, analysts can focus solely on the angle at which the blood initially struck the surface, minimizing potential distortion in their calculations.

One key principle in understanding the angle of impact is that as the angle becomes smaller, the tail of the bloodstain tends to be longer and more pronounced. This phenomenon occurs because, at a smaller angle, the blood droplets have a more oblique trajectory, resulting in elongated tails due to the influence of gravity and the velocity of the weapon or object.

In practice, analyzing the angle of impact allows investigators to make critical determinations regarding the positioning of the victim and assailant, the direction from which an attack occurred, and the type of weapon used. It is a fundamental aspect of bloodstain pattern analysis that, when combined with other factors, helps paint a comprehensive picture of the events that unfolded at a crime scene. Ultimately, the angle

of impact is a vital component in the toolkit of forensic experts, aiding them in unraveling the mysteries surrounding violent incidents and contributing to the pursuit of justice.

b. **Area of convergence:** The concept of the area of convergence plays a crucial role in determining the potential point of origin for spatter. This investigative technique involves the careful examination of string patterns. By meticulously analyzing these strings, investigators can discern vital information regarding the trajectory of the spatter. This analysis helps distinguish whether the spatter is in motion upwards, suggestive of a potential source location above, or moving downwards, which could indicate an origin point below. In essence, the area of convergence aids in piecing together the puzzle of a crime scene, offering valuable insights into the dynamics of the event.

c. **Determining height:** Accurate bloodstain analysis in a crime scene investigation hinges on establishing the precise height from which the blood droplets fell. This height measurement is pivotal as it offers crucial insights into the origin of these bloodstains. In complex scenarios, where both the victim and assailant potentially contribute to the spatter evidence, meticulously documenting these heights becomes paramount. Discrepancies in the correlation between bloodstain heights and the expected positions of the victim and assailant can unveil significant clues. By determining the victim's height, investigators can begin to deduce the likely sources of specific bloodstains, differentiating between those originating from the perpetrator and those attributable to the victim. This meticulous analysis plays a pivotal role in reconstructing the sequence of events and piecing together the narrative of the crime scene.

DOCUMENTRY ANALYSIS

(*Lanang Bumi Agung, 2023*) Research titled “Bloodstain pattern analysis” provided a systematic review of bloodstain pattern analysis (BPA) in forensic investigations, focused on its importance in cases involving violent crimes such as murder, assault, and sexual assault. It highlighted the lack of objective mathematical foundations in BPA as a critical issue that can affect the quality of evidence in trials. The review summarizes four papers that discussed various aspects of BPA, including the use of trigonometry to determine the angle of bloodstain impact. Experimental findings on the limitations of trigonometry in determining the height of blood spatter, the analysis of circular bloodstains indirectly determine the impact distance and origin, and the use of virtual models to accurately estimate the origin of blood stains. The paper also emphasized the complexity of BPA

and the importance of combining multiple methods to accurately interpret bloodstain patterns. It calls for further research to improve and develop new approaches for analyzing bloodstain patterns.

(Kacper Choroma, 2020) The research paper titled “Basics of Bloodstain Pattern Analysis” provided an overview of bloodstain pattern analysis in the field of forensics. The paper covered basic terminology, issues related to bloodstain patterns, and the methodology of forensic investigation in this area.

(Singh et al., 2021) The paper titled "Blood pattern analysis-a review and new findings" provided a comprehensive review of blood pattern analysis (BPA) and its importance in crime scene investigations. It also presented new experimental findings on blood stain formation using Awlata dye, which was conducted under laboratory conditions. The experimental findings in the paper established a relationship between the height of blood stains and the formation of satellite stains. It was found that as the height of dropping fake blood increased, the distance of satellite stains emerging from the fake blood stains also increased. From the take blood stains also increased. Additionally, the study found that the presence of spines in blood stains was inversely proportional to the height of the blood stains. The paper concluded that blood is a vital source of information in investigations and when interpreted correctly, it can aid in understanding what might have happened at the crime scene. The findings using fake blood stains can be used as a basis for future studies in blood pattern analysis.

(Lee et al., 2020) Research titled, “Study on development of forensic blood substitute: Focusing on bloodstain pattern analysis” focused on the development of a blood substitute for use in bloodstain pattern analysis in forensic science. The blood substitute developed in this study is more similar to human blood in terms of physical properties and drip bloodstain patterns. It is also practical to use as the materials used in its preparation are readily available in the market and do not include harmful chemicals. Additionally, the blood substitute has luminal reaction functionality and pattern transfer bloodstain dyeing functionality. Overall, the paper presents a study on the development of a blood substitute that addresses the limitations of existing substitutes in terms of similarity to human blood and practicality. The findings of this study have implications for improving the accuracy and reliability of bloodstain pattern analysis in forensic investigations.

(Sinisa franjic, 2019) Research titled “Bloodstain Pattern Analysis Provides Evidence during Crime Scene Investigation" focused on the importance of bloodstain pattern analysis in crime scene theories and statements made by suspects, victims, and witnesses. It highlighted the need for search measures and visualization techniques to identify and document traces of blood at crime scenes, including description, photography, sketching, and video documentation.

METHODOLOGY

This study employed an Experimental research design. It involved controlled experiments where various factors are manipulated to create blood spatter patterns. With Controlled experiment design where Blood spatter measurement was conducted in a controlled environment to minimize external variables. A clean and well-ventilated laboratory space was used for all experiments.

Sample of the Study: To get intended result I opted animal (Goat) blood to used as a samples for this study(Approximately 50 ml) why because both goat and animal blood have same in the Blood coagulation(Blood Clotting factor) values. With the help of this I selected Goat blood for analyzing to determine and analysis of the Bloodstain pattern.

Sample Preparation/Collection: Goat blood was collected from healthy adult goat under ethical and humane conditions. Animal welfare protocols and relevant permits were obtained.

Reliability and Validity: For fulfilling reliability and validity this sample were maintained under Hematological parameters (includes hematocrit, hemoglobin concentration, and clotting properties) for suit it for suitability for the study.

AIM OF EXPERIMENTS

- 1) To Know the knowledge about the bloodstain pattern analysis
- 2) To Determine And Measures The Size, Shape of The Blood Stain
- 3) To determine the origin point of the blood, angle of impact and height of the bloodstain.

Target Surfaces: Various target surfaces such as floor, wood, glass, and soil was selected to evaluate the impact of different materials on blood spatter patterns. With various Experimental Apparatus including bloodstain pattern analysis (BPA) kits, cameras, measuring scales, L scale, protractor ,dropper, hammer, cardboard and appropriate surfaces (e.g. soil, tiles or floor and wall) to create spatter patterns.

Data Recording: Capture spatters patterns using mobile cameras, ensuring adequate frame rate and resolution for detailed analysis. And Record information about experimental conditions, such as angle, distance, and height.

Analysis of Data: A Quantitative Analysis to Measure the Following aspects;

- Angle of impact.
- Size and shape of bloodstains.
- Dispersion patterns.

- Height calculation

Pattern Analysis: Bloodstain pattern analysis was measured and classified the spatter patterns according to recognized forensic criteria, such as impact angle, point of origin, and blood spatter type.

ETHICS AND SAFETY

Ethical Considerations: Ensure that all experiments involving animals (goat) comply with ethical guidelines and obtain necessary approvals from relevant authorities.

Safety Measures: Implement strict safety protocols to minimize risks associated with handling blood and experimental equipment.

RESULT AND DISCUSSION

I. TO KNOW THE KNOWLEDGE ABOUT THE BLOODSTAIN PATTERN ANALYSIS

Blood stain pattern analysis (BPA) is an important aspect of forensic science. It can provide valuable information about the location. Movement, object used, in violent crimes. Understanding the physical, chemical. And biological changes that occur during the drying of blood stains is also important in BPA. Bloodstain pattern analysis seeks to define the facts surrounding an investigation by the use of the physical nature of bloodstains. Bloodstain pattern analysis is the use of the size, shape, and distribution patterns of the bloodstains found at a crime scene to reconstruct the bloodshed events

Bloodstain patterns

Blood stains are classified into three basic types:

- Passive stains
- Transfer stains
- Projected stains

Passive stains: In forensic science, the term "passive" is a critical descriptor used to categorize bloodstains and patterns that result from the natural forces acting upon them during their formation. These forces primarily include gravity, air resistance, and the characteristics of the surface on which the bloodstains have been deposited. Passive bloodstains encompass a broad range of patterns and shapes, each revealing distinct insights into the dynamics of a crime scene. The main categories within passive bloodstain patterns are as follows:

Droplets: These are typically formed when blood falls freely and gravity shapes them into round or elongated shapes. The size and distribution of these droplets can provide valuable information about the height and angle of impact.

Pools: Pools of blood accumulate on a surface when a volume of blood has been released, often from a stationary source. The shape and size of the pool can help determine factors such as the amount of bloodshed and the time elapsed since the event.

Trails: Blood trails result from the movement of a bleeding individual or object through an area. These patterns can be linear or curved, and their analysis can provide crucial data about the sequence of events and the path taken by the person or object involved.

Understanding passive bloodstain patterns is essential in reconstructing crime scenes, deciphering events, and ultimately aiding law enforcement agencies in their pursuit of justice. Accurate interpretation of these patterns requires both a scientific approach and a keen eye for detail, ensuring that justice is served based on evidence-driven analysis.

Droplets: The term "droplets" refers to small liquid drops with relatively high viscosities, which mean they have a tendency to form a solid stream rather than dispersing into a fine spray of tiny droplets. The behavior of these droplets is significantly influenced by the characteristics of the surface on which they land. To gain a deeper understanding of this phenomenon, researcher conducted a series of experiments both indoors and outdoors, focusing on the impact of surface texture on bloodstain patterns. For this investigation, we selected goat blood as our test substance and examined its behavior on both smooth and rough surfaces.

And the diameter of the resulting bloodstains or chance blood stains increased proportionally with the height from which the blood was dropped. This height-dependent variation in stain size underscores the importance of considering the vertical dimension when analyzing blood spatter patterns. Moreover, the influence of surface texture on bloodstains became apparent. On smooth surfaces, the blood tended to form nearly perfect spheres upon impact, exhibiting a more predictable and uniform pattern. Conversely, on rough surfaces, the interaction between the blood and the irregularities of the surface often led to the creation of spatters, with irregular shapes and dispersion. This observation underscores the paramount importance of surface texture in the interpretation of bloodstain patterns, as it can significantly affect the appearance and characteristics of the resulting patterns.

The behavior of blood droplets upon impact is a complex interplay of factors such as viscosity, height of release, and, notably, the texture of the landing surface. Understanding

these dynamics is crucial for accurate interpretation and reconstruction of bloodstain patterns in forensic investigations, ultimately aiding in the pursuit of justice by providing valuable evidential insights.

II. TO DETERMINE AND MEASURES THE SIZE, SHAPE OF THE BLOOD STAIN

This Objective is Explore and to determine the Different Size and Shape of the Blood stains

Blood drop on smooth surface: Here the researcher measured sampled blood from the Smooth surface.

Table No -01

SMOOTH SURFACE		
Height	Length	Width
1Ft	1.5cm	2.8cm
2Ft	1.8cm	2.9cm
3Ft	2.1cm	03cm
4Ft	4.1cm	3.2cm

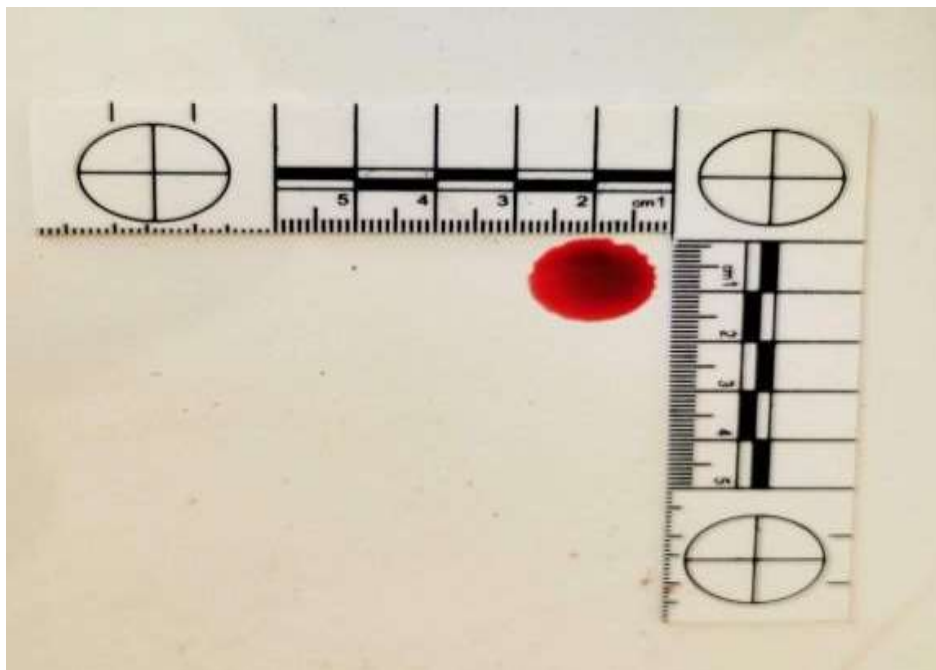


Image-01: Smooth surface

The above table explored about the data which, the blood spatter was measured on the Smooth surface; with the help of that measurement the researcher concluded that there is as pattering in the blood and it various depends upon Height. If the height increases vice versa the length and width

measurement of the bloodstain also increases. If the height decreases the length and width measurement of blood stain also decreases.

Table No -02
ROUGH SURFACE

Height	Length	Width
1ft	1cm	2.5 cm
2ft	1.1cm	2.6cm
3ft	1.3cm	3.4cm
4ft	1.9cm	3.6cm

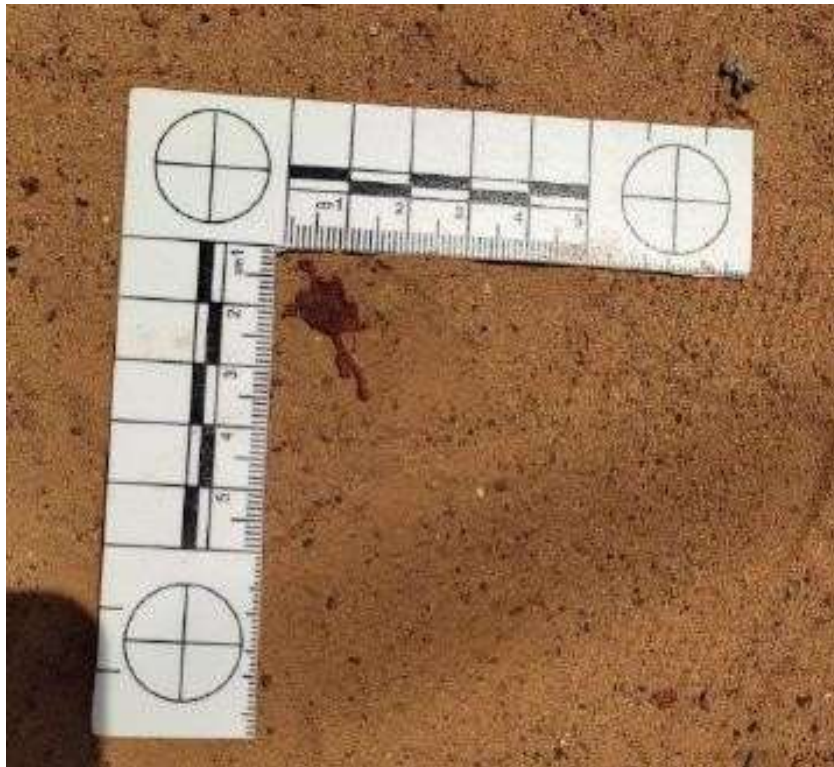


Image- 02: Rough Surface

The above table explored about the data which was measured the blood spatter on the Rough surface, with the help of that measurement researcher concluded that the spattering of blood and it various is depends upon Height. If the height increases vice versa the length and width measurement of the bloodstain also increases. If the height decreases the length and width measurement of blood stain also decreases.

Pool: Blood pooling is a critical bloodstain pattern that occurs when a substantial volume of blood accumulates and forms a puddle on the ground or a surface. To gain insights into the dynamics of blood pooling, researcher conducted experiments involving the controlled release of blood onto various surfaces using adjustable heights. In these experiments, researcher sought to explore how different types of surfaces—specifically, porous and nonporous ones—can influence the formation of blood pools. Porous surfaces, such as smooth textiles, have the capacity to absorb some of the blood, altering the way it spreads and interacts with the surface. On the other hand, nonporous surfaces, like soil, do not absorb the blood, allowing it to pool more readily. When blood was dropped onto porous surfaces, it exhibited unique behaviors. The blood tended to be partially absorbed by the material, causing irregularities in the pool's shape and size. In contrast, on nonporous surfaces, the blood remained relatively intact, forming more consistent and recognizable pool patterns. These experiments underscore the importance of understanding the nature of surfaces in bloodstain pattern analysis. The distinction between porous and nonporous surfaces significantly influences the appearance and interpretation of blood pool patterns. Accurate recognition and interpretation of these patterns are vital in forensic investigations, as they provide crucial information about the events that transpired at a crime scene, contributing to the pursuit of justice through evidence-based analysis.



Image- 03: Pool Blood Stain

Porous Surface of Blood: The figure labeled as Image- 03 illustrates the impact of surface texture on bloodstain patterns. A porous surface, characterized by numerous small holes, allows both blood and air to pass through, albeit at a relatively slow rate. This permeability influences how a drop of blood interacts with the surface. The texture of the target surface is a critical determinant in shaping the resulting bloodstain pattern, affecting its size, shape, and overall appearance. Understanding

this interplay between surface texture and blood behavior is essential for accurate forensic analysis, as it aids in the interpretation of bloodstain patterns at crime scenes, ultimately assisting in the reconstruction of events and the pursuit of justice.



Image- 04: Non Porous Surface of Blood

As shown above **Image- 04** non porous surface will create a spatters and soil absorbs the blood.

Trails: Blood trails are a distinctive bloodstain pattern characterized by the presence of relatively large blood drops arranged in a linear fashion. These drops are typically deposited on a horizontal surface as they drip from the source of blood, creating a unique and telling pattern. The linear arrangement of the drops provides valuable information about the direction and movement of the blood source, making blood trails a critical component of bloodstain pattern analysis in forensic investigations. Accurate recognition and interpretation of these patterns contribute significantly to the reconstruction of events, helping investigators piece together the sequence of actions at a crime scene and aiding in the pursuit of justice.



Image- 05: Trails Blood

Transfer blood: A blood transfer pattern occurs when an object or surface that lacks blood comes into contact with an object or surface that is bloodied. In my experiments, researcher utilized both shoes and palms to intentionally create blood transfer patterns for analysis. The two primary types of blood transfer patterns are swipe and wipe pattern transfers.

Swipe pattern transfers involve direct contact between the blood-bearing object and the recipient surface, leaving a recognizable impression that mirrors the shape and characteristics of the object. This type of transfer can yield valuable information about the object's orientation and the dynamics of the contact. Wipe pattern transfers, on the other hand, occur when an intermediary object, such as a person's hand, comes into contact with the blood-bearing object and subsequently makes contact with the recipient surface. This results in a pattern that may differ from the object's actual shape, introducing complexities in the analysis process. The study of blood transfer patterns is crucial in forensic science, as it allows investigators to establish connections between objects, individuals, and crime scenes. Understanding the nuances between direct and indirect transfers

enhances the accuracy of crime scene reconstruction and the development of a comprehensive narrative, thereby aiding in the pursuit of justice.

Swipe pattern: Blood transfer onto a clean surface, often referred to as a swipe pattern, occurs when a bloodied object, such as a shoe, comes into contact with an uncontaminated surface. Swipe patterns are an essential element of bloodstain pattern analysis, providing insights into the sequence of events at a crime scene.



Image- 06: Swipe pattern

Wipe pattern: In a wipe pattern, a hand or object moves through wet blood, causing the blood to be smeared or wiped across a surface. This pattern is particularly significant in bloodstain pattern analysis, as it signifies movement within a crime scene and can help reconstruct the sequence of events.



Image- 07: Wipe Blood Stain

Projected Blood: Blood spatter patterns, such as those resulting from impact, provide crucial insights into crime scene dynamics. Impact patterns are categorized into three main types: low impact velocity, medium impact velocity, and high impact velocity. While this experiments focused on low impact velocity, constraints related to tool availability prevented us from conducting experiments on the remaining two impact velocities.

In low impact velocity experiments, researcher used a hammer to replicate the effects of blunt force on blood spatter. These patterns are particularly relevant in forensic analysis, as they can help determine the direction of the blood source and contribute to crime scene reconstruction. While limitations restricted our exploration to low impact velocity, it underscores the importance of further research and access to tools to comprehensively understand the full spectrum of blood spatter patterns and their implications in forensic investigations.

Image- 08 Point of Origin

Point of Origin: The determination of the point of origin in an impact pattern is a critical step in reconstructing the sequence of events in a bloodletting incident. To ascertain this pivotal piece of information, researcher employed a set of tools and procedures, including a hammer, measurement scale, thread, protractor, and calculator.

The process involved meticulous examination and analysis. Researcher carefully measured and documented the dimensions and angles of bloodstains using the measurement scale and protractor. By suspending threads from various impact points and meticulously measuring their angles and lengths, researcher could triangulate and calculate the point of origin using trigonometric

principles. These procedures were carried out with precision, allowing for the determination of the exact point in space from which the blood originated. This information plays a crucial role in forensic investigations, aiding in the reconstruction of the incident and helping law enforcement agencies establish a coherent and evidence-based narrative of the events that transpired during the bloodletting incident.



Image- 08 Point of Origin

Step 1: First step is to determine the direction of blood flow in the drops follow with an arrow next to the droplet. The angle of impact was less than 90 degree so the shape was not circular or elliptical. If the blood drop is circular the blood fell at a 90 degree angle.

Step 2: From several drops of blood, researcher determined the area of convergence by drawing lines through each of the blood droplets and noting where the lines intersect.

Step 3: and measured the distance from the area of convergence to the edge of the drop of blood when it first impacted a surface.

Step 4: To determining the angle of impact for each droplet of blood. Used the law of sines. In this step I have selected each droplet individually and determined the angle of impact of the blood. To measure the length of the blood droplet we should not include a thin extension of the leading edge.

Angle of impact = width of the blood/ length of the blood drop

Angle of impact = (W/L)Sin

W= width of the bloodstain

L= Length of the bloodstain

The table showing the Distance of each blood droplets which were collected, Measured and noted in tabulated **No: 03**

Table No-03

Length	width
0.7cm	0.3cm
0.6cm	0.3cm
0.5cm	0.3cm
0.5cm	0.3cm
0.5cm	0.2cm
0.5cm	0.3cm
0.6cm	0.4cm
0.4cm	0.3cm

Each blood droplets length and width should be consider in Mili Meter (mm) and scaling

1cm is equal to 10mm/(1cm = 10mm)

Table No: 04

Width in mm	Length in mm	w/l in mm	Sin-1 in degree
3	7	0.42	47.5
3	6	0.5	30
3	5	0.6	36.86
3	5	0.6	36.86
2	5	0.4	23.57
3	5	0.6	36.86

4	6	0.66	36.86
3	4	0.75	48.59

By using scale and noted the values and tabulated in the Table No: 04

Calculation:

- 1) Angle of impact = $(W/L)\sin^{-1}$
 $= (3/7) \sin^{-1}$
 $= (0.42) \sin^{-1}$
 $= 47.5^\circ$
- 2) Angle of impact = $(3/6) \sin^{-1}$
 $= (0.5) \sin^{-1}$
 $= 30^\circ$
- 3) Angle of impact = $(3/5) \sin^{-1}$
 $= (0.6) \sin^{-1}$
 $= 36.86^\circ$
- 4) Angle of impact = $(3/5) \sin^{-1}$
 $= (0.6) \sin^{-1}$
 $= 36.86^\circ$
- 5) Angle of impact = $(2/5) \sin^{-1}$
 $= (0.4) \sin^{-1}$
 $= 23.57^\circ$
- 6) Angle of impact = $(3/5) \sin^{-1}$
 $= (0.6) \sin^{-1}$
 $= 36.86^\circ$
- 7) Angle of impact = $(4/6) \sin^{-1}$
 $= (0.66) \sin^{-1}$
 $= 36.86^\circ$
- 8) Angle of impact = $(3/4) \sin^{-1}$
 $= (0.75) \sin^{-1}$
 $= 48.59^\circ$

Step 5: I have determined the height by applying law of tangents. Trigonometry has a large and important role in bloodstain pattern analysis.

Tan of angle of impact = Z / Distance

$Z = \tan(\text{angle of impact}) * \text{measured distance}$

Z= height, D= distance

Table No: 05 Measured Value to determine the Tan of angle

Measured distance in cm	Angle of impact	Tan(angle of impact)	Height(Z)
47.5	47.5	1.0913	51.8
41	30	0.5773	23.669
48	36.86	0.7497	35.98
42.5	36.86	0.7497	31.862
46	23.87	0.4362	20.065
43.5	36.86	0.7497	32.611
47	36.86	0.7497	35.23
30	48.59	1.1338	34.014

Calculation: To Computing the Height of the Blood Dropped

- 1) $Z = \tan(\text{angle of impact}) * \text{measured distance}$
 $= 1.0913 * 47.5$
 $= 51.8\text{cm}$
- 2) $Z = 0.5773 * 41$
 $= 23.669\text{cm}$
- 3) $Z = 0.7497 * 48$
 $= 35.98\text{cm}$
- 4) $Z = 0.7497 * 42.5$
 $= 31.862 \text{ cm}$
- 5) $Z = 0.4362 * 46$
 $= 20.065 \text{ cm}$

$$6) Z = 0.7497 * 43.5 \\ = 32.611 \text{cm}$$

$$7) Z = 0.7497 * 47 \\ = 35.23 \text{cm}$$

$$8) Z = 1.1338 * 30 \\ = 34.014 \text{cm}$$

To evaluating the Mean height of the Blood Dropped

$$\text{Mean} = \frac{51.8 + 23.669 + 35.98 + 31.862 + 20.065 + 32.611 + 35.23 + 34.014}{8} \\ = \frac{265.231}{8} \\ = \mathbf{33.153 \text{ cm}}$$

But we know that 1cm = 1 ÷ 30.48 ft

$$= 0.0328084 \text{ Ft}$$

$$\text{So that} = 33.153 * 0.0328084$$

$$= \mathbf{1.087 \text{ Ft}}$$

The calculation resulted that the blood originated/ Dropped from the height of **1.087 Ft.** by using Trigonometry application.

CONCLUSION

Bloodstain pattern analysis (BPA) is a crucial tool employed by forensic scientists to aid in the reconstruction of violent crimes and try to find out what causes behind the action. The primary objective of this experiment was to gain knowledge about different stain patterns, including passive, projected, and transfer patterns. These stain patterns play a pivotal role in understanding crime scenes, shedding light on the dynamics of violent incidents. By analyzing these patterns, investigators can reconstruct the sequence of events and gather critical evidence for solving crimes. It shows that the shape (length and Width) of bloodstain patterns changes based on the surfaces where we get chance stains at crime scenes.

This study also demonstrated to find out the blood angle of impact and the height of the dropped point; means which experiment illustrated the origin point of blood dropping and the exact height of the blood dropping means that relate to the perpetrator's action in the particular crime.

These observational findings emphasizing and illustrating the complex interplay of factors influencing bloodstain patterns and underscores the importance of careful analysis in forensic investigations. Such experiments with surrogate blood sources, like goat blood, offer valuable insights into the behavior of blood spatter, aiding forensic experts in reconstructing crime scenes and contributing to the pursuit of justice.

Droplet Size Variation: The size of blood droplets was observed to vary depending on the height from which the blood was dropped. Higher drops resulted in larger droplets, indicating a direct correlation between drop height and droplet size.

Surface Texture Influence: Bloodstain patterns exhibited notable differences when dropped onto various surfaces. On smooth, non-porous surfaces, such as glass, the blood formed welldefined circular stains with minimal irregularities. In contrast, on rough and porous surfaces like fabric, the stains often appeared more diffuse and irregular due to blood absorption.

Impact Angle Impact: The angle at which blood droplets struck the surface influenced the shape of the resulting stains. When the drops were released at an angle closer to perpendicular, the stains were more circular, while oblique angles resulted in elongated or elliptical shapes.

Saturation and Absorption: The absorption capacity of different materials affected the degree of saturation in the bloodstains. Porous materials, like cardboard, absorbed the blood more readily, leading to less visible and more diffuse stains compared to non-porous surfaces like glass.

Velocity and Spatter: Experiments involving higher velocity impacts, mimicking forceful bloodshed, resulted in spatter patterns characterized by smaller droplets dispersed in a radial pattern around the impact point. Lower velocity impacts produced fewer and larger stains.

Transfer and Swipe Patterns: The use of hands, objects, or shoes to create transfer and swipe patterns was successful in replicating real-life scenarios. These patterns exhibited the directional movement of blood, which can aid in the reconstruction of events.

Pooling: When a substantial volume of blood was deposited on a surface, it accumulated to form pools with varying shapes, depending on the surface characteristics. Porous surfaces absorbed some blood, affecting the pool's appearance.

Point of Origin Calculation: By triangulating blood spatter patterns and angles, the point of origin of the bloodshed could be calculated with reasonable accuracy, providing insights into the location of the blood source.

Funding and/or Conflicts of interests/Competing interests

DECLARATION

Authors' contributions: I, Vinayak Nidasosi, being Co-author declare that, I am submitting following research article title **“BLOOD STAIN PATTERN: AN EXPERIMENTAL ANALYSIS OF BLOOD IN FORENSIC SCIENCE.”** The above mentioned research article is authored by jointly with: * **Vijeta S Alavani** & ** **Mr. Vinayak Nidasoshi**.

I have informed all the co-authors about this submission, and that none of them has a any objection regarding the data / maps / photographs / drawings / illustrations / flow charts, etc. being used for this contribution.

Availability of data and material: All the data/ maps/ photographs/ drawings/ illustrations/ flow charts, etc. being used for this research article is my own/ I have obtained necessary permission from the concerned persons or institutions for using these, and am inclosing a copy of the same.

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Competing interests: I declare that getting necessary permissions for gathering the data and related information presented in the article is my responsibility. I am aware of that the Indian Society for Prehistoric and Quaternary Studies and the Journal will not be responsible for and involved in any ramifications arising thereafter.

Ethics approval and consent to participate: I am aware of all provisions of the Copyright Act 1957 enacted by Parliament in the Eighth Year of the Republic of India [No. 14 of 1957 as amended up to act 65 of 1984], and the procedures dealing with infringement of the copyrights. I have

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Co-Author Name: Vinayak Nidasosi

Address: Rani Channamma University, Belagavi-591156.

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