Exploring Bloodstain Patterns on Different Paper Substrates as Forensic Indicators: An Approach in Crime Scene Investigation

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Abstract: ***Bloodstain Pattern Analysis (BPA) can provide valuable information about the circumstances surrounding blood deposition and is therefore relevant to forensic investigation. The nature of the receiving surface can influence the size, shape and other morphological characteristics of a bloodstain. The present study evaluated the effects of paper type, drop height and impact angle on bloodstain morphology. Human blood was deposited on seven paper substrates: copier paper, glossy paper, glaze paper, chart paper, newspaper, tissue paper and wet tissue paper. Blood drops were released from heights of 1-7 ft at impact angles of 90°,60° and 30°, with each experimental condition repeated three times. After natural drying, the stains were photographed and examined for shape, diameter, spike formation and satellite stains. Mean and standard deviation were used to summarize the quantitative observations. The findings showed a general increase in stain diameter with increasing drop height. Stains produced at 90° were predominantly circular, whereas lower impact angles resulted in progressively more oval and elongated patterns. Glossy and glaze papers generally preserved clearer stain boundaries, while tissue and wet tissue papers showed greater spreading and distortion. Glossy paper exhibited the highest spike counts, whereas tissue paper showed the highest observed mean satellite-stain counts.***

Keywords: Bloodstain pattern Analysis (BPA); paper substrates; drop height; impact angle; spike formation; satellite stains

1. Introduction

Bloodstain Pattern Analysis (BPA) is one of the crucial aspects of forensic science that deals with examining and interpreting bloodstain properties and patterns to interpret events surrounding blood spatter. The shape of a bloodstain is determined by such factors as the speed and direction of a blood drop, the height from which the blood was dropped and the surface on which the blood landed. The characteristics of blood spatter stain, including its shape, size, edges and secondary projections such as spikes and satellites, are determined by the interaction with the surface (Attinger et al.,2013; Laan et al.,2015). Paper materials are often encountered as surface on which biological stains may be deposited or preserved. However, different papers differ in their surface texture, porosity, absorbency, and physical structure, which can affect the appearance and preservation of bloodstain patterns. The receiving surface is an important factor that must be taken into account when interpreting bloodstain morphology in forensic examination (James et al.,2005; Silenieks,2024).

The purpose of this research was to compare the differences in bloodstains formed on different paper substrates under the same conditions. The experiment was conducted to observe the patterns of bloodstain diameter, shape, spikes and satellite formation that depend on the properties of paper materials.

2. Methodology

The experimental study was conducted in the Biology and Serology Laboratory, Department of Forensic Science, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj. **Seven paper substrates**- copier paper (**75g/m^2**), glossy paper (**180 g/m^2**), glaze paper (**110 g/m^2**), chart paper (**200 g/m^2**), newspaper/ The Indian Express (**42 g/m^2**), 2-ply tissue paper (**25 g/m^2**), and wet tissue paper (**50 g/m^2**), were selected and procured from local market in Prayagraj. Human blood samples were obtained from a pathology laboratory in Prayagraj from donors aged 20-30 years and stored under refrigerated conditions until use. A fixed volume of 1.5 ml was used for deposition. Blood was released with a dropper from heights of 1-7 ft and at impact angles of 90°, 60° and 30°. Each height-angle-substrate condition was repeated three times, while the experimental setup and release conditions were kept as uniform as possible. After deposition, stains were allowed to dry naturally at room temperature. Photographs were taken under standardized conditions and examined for stain diameter, shape, spike formation, and satellite stains. Stain diameter was measured across the widest portion of each stain, while spike and satellite stain formations were recorded from the resulting bloodstain patterns. Mean and standard deviation were used to summarize the repeated observations. The study therefore emphasizes descriptive comparison rather than inferential claims.

3. Results

The experimental observations showed that the appearance of the bloodstains changed with both the paper surface and the conditions under which the drops were deposited. At lower heights, most substrates produced relatively regular stains. With increasing height, irregularity became more noticeable, especially on tissue and wet tissue paper. Glossy and glaze paper generally retained clear and more regular outlines. The angle of impact produced a consistent change in shape. At 90°, the stains were circular across all seven substrates. At 60°, the stains were predominantly oval, whereas at 30°, they became more elliptical or elongated. This trend was particularly noticeable on tissue and wet tissue paper, where absorption contributed to greater distortion.

Table 1: Mean Bloodstain Diameter (cm) at Different Angles

Paper Substrates	90°	60°	30°
Glossy paper	1.61	1.8	1.85
Glaze paper	1.77	1.91	1.9
Copier paper	1.84	2.1	2.15
Newspaper	1.54	2.16	2.26
Chart paper	1.79	2.08	2.17
Tissue paper	2.67	3.16	3.4
Wet tissue paper	0.76	1.09	1.22

Table 2: Mean Bloodstain Diameter (cm) at Different Heights

Height (ft)	Glossy paper	Glaze paper	Chart paper	Copier paper	News-paper	Tissue paper	Wet tissue
1 ft	1.43	1.60	1.43	1.49	1.84	2.70	0.62
2 ft	1.49	1.74	1.71	1.74	1.88	2.82	1.05
3 ft	1.61	1.79	1.87	1.78	2.0	2.84	1.12
4 ft	1.76	1.84	1.91	1.91	2.1	2.89	0.96
5 ft	1.92	1.86	2.00	2.10	2.16	3.06	1.84
6 ft	1.99	1.88	2.53	2.14	2.29	3.58	1.27
7 ft	2.00	2.20	2.63	3.03	2.44	3.64	1.30

Table 3: Spike Count by Height

Height (ft)	Glossy paper	Glaze paper	Chart paper	Copier paper	News-paper	Tissue paper	Wet tissue
1 ft	21	18	15	19	13	8	2
2 ft	27	25	22	20	15	11	3
3 ft	33	25	28	23	18	13	3
4 ft	35	28	30	26	21	15	4
5 ft	41	30	29	28	23	18	4
6 ft	43	33	32	29	26	21	4
7 ft	45	35	34	32	29	23	4

Table 4: Spike Count by Impact Angle

Impact Angle	Glossy paper	Glaze paper	Chart paper	Copier paper	News paper	Tissue paper	Wet tissue
90°	31	28	24	23	18	13	2
60°	33	27	28	25	21	18	4
30°	36	33	31	28	25	22	4

Table 5: Mean Satellite-Stain Count by Height

Height (ft)	Glossy paper	Glaze paper	Chart paper	Copier paper	News-paper	Tissue paper	Wet tissue
1 ft	0	0.3	1	0.7	1.3	2	0.2
2 ft	0.3	0.7	1.3	1	1.6	2.7	0.8
3 ft	0.7	1	1.7	1.3	2.1	3.3	1
4 ft	1	1.3	2.3	1.9	2.6	4	1.3
5 ft	1.3	1.7	2.7	2.1	3.1	4.6	1.8
6 ft	1.7	2	3	2.5	3.7	5.1	2
7 ft	2	2.3	3.3	2.7	4.1	6	2.3

Table 6: Mean Satellite-Stain Count by Impact Angle.

Impact Angle	Glossy paper	Glaze paper	Chart paper	Copier paper	News paper	Tissue paper	Wet tissue
90°	0.7	1	1.7	1.3	2.3	3	1
60°	1.3	1.7	2.3	2	3	4.3	1.7
30°	2	2.1	3.3	2.7	3.9	6	2.3

Table 7: Shape According to Impact Angle

Impact Angle	Observed Shape
90°	Circular/ predominantly circular.
60°	Oval.
30°	Elliptical or elongated elliptical.

4. Discussion

The present study demonstrated that paper substrates, drop height, and impact angle influenced bloodstain morphology. Mean diameter generally increased with increasing drop height, which may be associated with changes in the velocity and impact behaviour of the falling blood drop. **The interaction between droplet dynamics and the receiving surface is an important factor in bloodstain formation** (Attinger et al.,2013; Laan et al., 2015).

The increase in stain diameter with drop height can be considered in relation to the greater velocity acquired by the falling drop before impact. Similarly, the stains formed at 90° were mainly circular, while those produced at 60° and 30° became progressively oval and elongated (Connolly et al., 2012). The satellite-stain observations also show that the surface should not be treated as a neutral background. The type of paper also influenced stain appearance. Glossy and glaze papers produced comparatively clearer and better-defined stains, while tissue and wet tissue showed greater spreading and absorption. This may be explained by differences in surface texture, porosity, and absorbency. **Similar substrate-dependent differences were emphasized that absorbent surfaces can alter stain size, edges, and overall pattern preservation** (Silenieks,2024; Rajkumari, 2024).

The formation of these peripheral features is influenced by the behaviour of the blood during impact and the characteristics of the receiving surface (Adam, 2012). This is particularly important when bloodstains are encountered on paper-based materials at crime scenes, since absorption and surface texture may modify the appearance of the original stain (James et al.,2005; Silenieks,2024; Singh et al.,2021). The present work was performed under controlled laboratory conditions and examined a group of paper products.

5. Conclusion

The present study demonstrates that paper substrates, drop height and impact angle collectively influence bloodstain morphology. Increasing drop height was generally associated with an increase in stain diameter and the development of additional peripheral features under the experimental conditions. Decreasing the impact angle resulted in progressively more elongated stains, with higher observed spike and satellite-stain count. Glossy and glaze papers provided comparatively clear and well-preserved patterns, while tissue and wet tissue paper showed greater absorption, spreading and distortion. These findings emphasize that the characteristics of the receiving paper surface should be considered along with drop height and impact angle during the forensic interpretation of bloodstains deposited on paper-based materials.

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