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ORIGINAL ARTICLE

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Experimental bloodstains on fabric from contact and from droplets

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Abstract The differentiation between contact bloodstains and stains produced by projected droplets on fabric can be crucial in crime scene reconstruction since suspects can explain bloodstains on their clothing by contact with the victim post mortem. Experimental smear and contact pressure stains on three different types of fabric were compared with stains produced by falling and projected droplets ("dynamic" stains) of equivalent size. The morphology of the small stains (0.1–10 µl) was investigated with a macroscope. Characteristic for "dynamic" stains are symmetry and rhythmicity (secondary droplets) of the stain and a zonal drying pattern. Contact stains lack the characteristic features of "dynamic" stains and show a clear impregnation of the material resulting in a blood-soaked reverse side of cambric and cotton and in a paler overall colour. The mode of formation of microstains (blood volume 1 < µl) on irregular surfaces (e.g. terry cloth) can be difficult to determine since the rough surface structure and the small blood volume reduce the characteristics of dynamic stains. In these cases, comparison with experimental stains on the same surface material is recommended.

Key words Bloodstain morphology · Contact stains · Fabrics · Microstains

Introduction

The interpretation of bloodstain patterns can play a vital role in crime scene reconstruction. One important aspect is the differentiation between contact stains and stains formed dynamically after a period of flight. However, the experimental investigation of bloodstains has concentrated on dynamic forms where the blood itself is in motion in the form of falling droplets (e.g. Lochte 1932), projected droplets (e.g. Balthazard et al. 1939; Brinkmann et al. 1985; Pizzola et al. 1986) or backspatter (e.g. Pex and Vaughan 1987; Karger et al. 1996, 1997). Bloodstains originating from contact with an already bloody surface have rarely been investigated systematically since they are allegedly easy to recognize (e.g. Ziemke 1914). But in our experience this is only true for large stains. Small stains and especially microstains (droplet volume 1 < µl) formed by contact with a bloody surface are sometimes difficult to differentiate from falling or projected droplets of equivalent size. In recent case examples this differentiation was requested when the suspects explained tiny blood stains on their clothing by contact with the victim post mortem. Therefore, this study was initiated to investigate regularly occurring differences between the morphology of contact stains and those caused by falling or projected droplets on fabric.

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Materials and methods

Contact stains can be produced by an object touching a bloody surface (direct contact stains) or by a bloody object touching a surface (indirect contact stains). Both forms can be caused by local pressure (pressure contact stains) or by moving an object along a surface (smear contact stains). These four forms of stains were produced experimentally. In case work, bloodstains often occur on different types of clothing and therefore the materials utilized in this study were bed sheeting (100% cotton), cambric (shirt material, 65% polyester and 35% cotton) and terry cloth (85% polyester and 15% cotton). Additionally, good quality typing paper was used as a control surface in preliminary studies.

The blood used was of human origin with heparin as an anticoagulant. The blood volumes used were: 10.0, 5.0, 1.0, 0.5, 0.25 and 0.1 µl. The first two volumes were measured and released from conventional pipettes (Eppendorf), the smaller volumes were produced by a precision syringe (Dynatech). Each volume was used five times to produce each of the four forms of contact stains on the three different fabrics. Both an uncovered finger tip and a finger covered with fabrics were utilized for touching the fabrics.

For comparison with contact stains several series of falling (90° impact angle, i.e. horizontal position of the substrate) and projected (60–10° impact angle) droplets of different volumes and from different heights were produced on the same three fabrics. The intention was to produce stains as similar as possible to con-

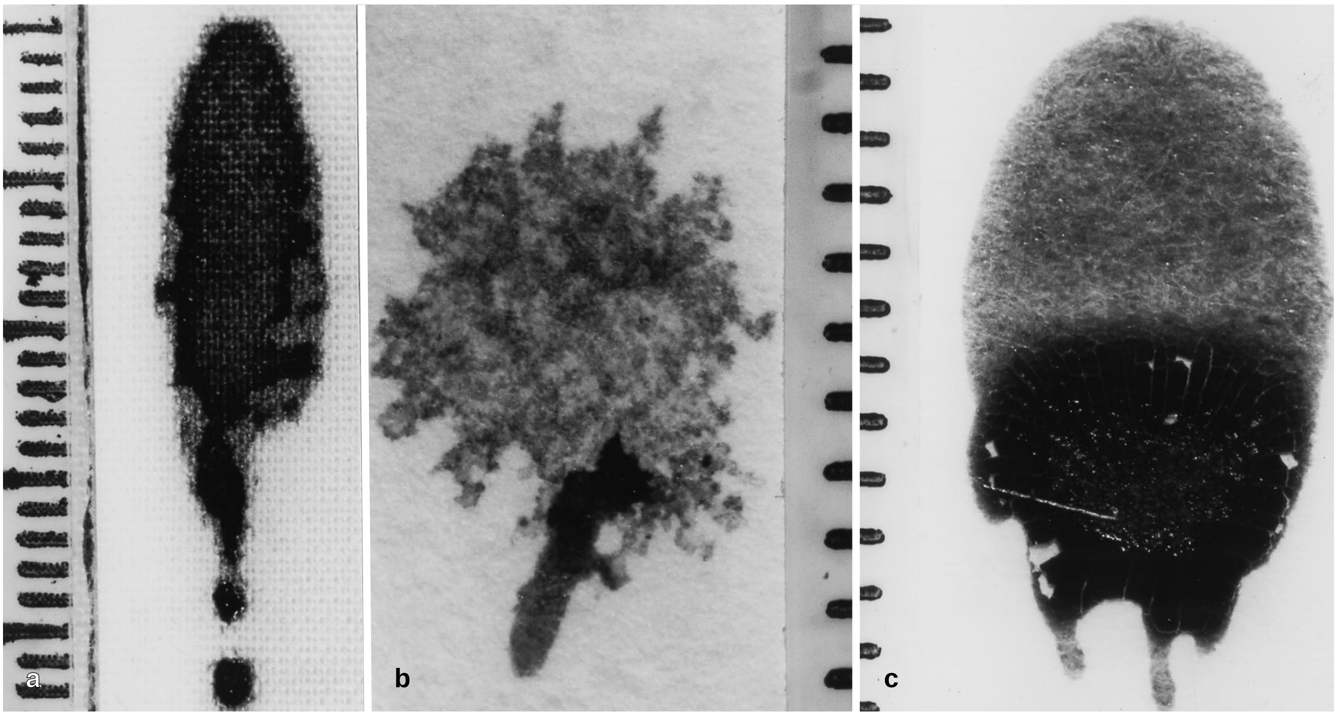


Fig. 1a Stain (“exclamation mark”) from a projected droplet on cambric, drop volume 13.0 µl, impact angle 30°, drop height 70 cm. The zonal arrangement of the stain (pale central zone, outer ring rich in blood, marginal diffusion zone) is clearly visible. The lower pole is slightly asymmetrical due to the textile structure. Scale in mm. **b** Contact pressure stain on paper, drop volume 0.5 µl. The lower zone rich in blood, which is completely different from the outer ring rich in blood or the horizontal zonal arrangement in dynamic stains (Fig. 1a,1c), represents the point where the small blood volume on the fingertip was in direct contact with the paper. Scale in mm. **c** Typical “bear paw”-shaped stain from a projected droplet on paper. Drop volume 9.0 µl, impact angle 40°, drop height 120 cm. The horizontal zonal arrangement of the blood is due to the angular impact. Scale in mm

tact stains regardless of the blood volume used. The stains were investigated with a macroscope M 400R (Wild).

Results

Stains from projected or falling droplets share some common characteristics (Brinkmann et al. 1985) which may form the basis for a differentiation from contact stains as follows:

- symmetry of the shape (compare Fig. 1c, 2b).
- composed pattern with surrounding secondary and tertiary droplets and/or rhythmicity, especially in cases of angular impact with the formation of “hopping patterns” (Fig. 1, compare Fig. 2b, 3c).
- zonal arrangement of the stain after drying including a central zone poor in blood, an outer ring rich in blood and a marginal diffusion zone (Fig. 1a, compare Fig. 2b).
- horizontal zonal arrangement, especially in cases of angular impact or if the substrate is at an angle (compare Fig. 1c).

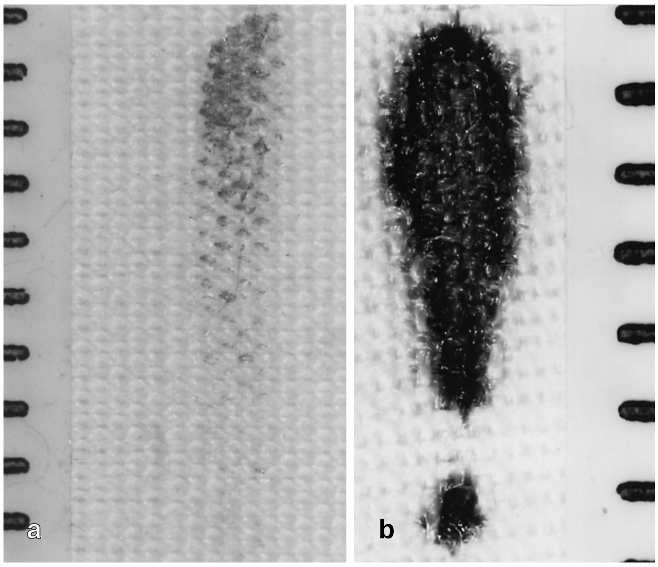


Fig. 2a Contact smear stain on cambric, drop volume 0.1 µl. The smear tailing fades away in the direction of the smear and the impregnation of the ridges is predominantly on the side facing the smearing direction. Scale in mm. **b** Stain from a projected droplet on cambric, drop volume 0.5 µl, impact angle 30°, drop height 90 cm. The zonal arrangement of the classical exclamation mark is visible despite the small volume. Scale in mm

The stains on paper can be regarded as “ideal forms” as they are practically unaffected by the surface structure of the material. Direct smear stains are represented as long, continuous smears without a zonal drying pattern or irregularities. Indirect smear stains are similar but can show discontinuities. Pressure contact stains are oval to circular and also lack a zonal drying pattern (Fig. 1b). The stains show irregular or fissured edges which can easily be distinguished from typical "bear paw" shapes (Fig. 1c) or "crown shaped" edges of falling stains. On fabrics, the results from different objects used (finger vs. fabric) and from direct and indirect stains can be summarized because these differences in the production of stains did not lead to regularly occurring differences.

1. Smear stains

Cambric

The stains have an oval to elongated shape (Fig. 2a). The smear tailing contains less blood than the beginning of the stain – contrary to exclamation marks (Fig. 2b). The tailing therefore only results in a superficial impregnation of prominent parts of the fibres (Fig. 2a). This impregnation frequently shows asymmetry in that it is predominantly at the sides of the fibre ridges facing the smearing direction. Secondary droplets or a marginal diffusion zone are lacking (Fig. 2a), an outer ring rich in blood can only be seen when the blood volume is 5 µl or more. In these cases, the blood volume exceeds the surface of the finger tip.

Cotton

The highly absorbent quality of the fabric produces a circular to irregular stain soaked with blood if the blood volume is > 0.25 µl (Fig. 3a). Consequently, the reverse side of the fabric is also soaked with blood (Fig. 3b), which is not the case in stains from projected blood (Fig. 3c). The superficial impregnation of the smear tailing is similar to the smear stains on cambric except for small blood volumes, where only a faint colouring was observed.

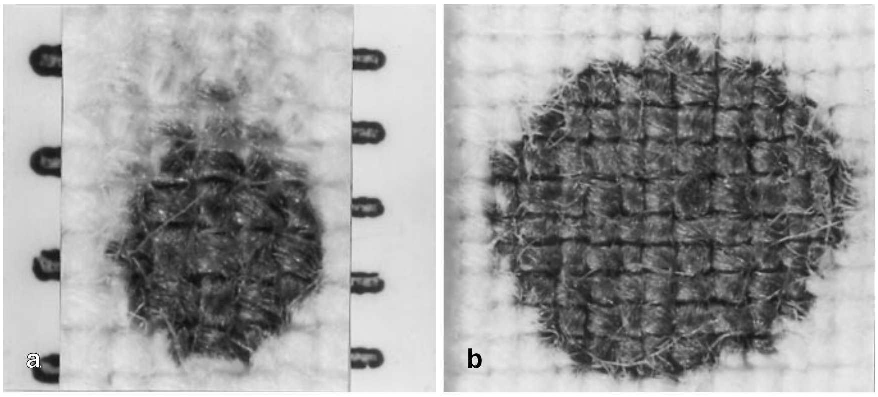
Terry cloth

The rough and projecting surface structure of the fabric renders a differentiation of smear stains from stains from projected blood difficult. The latter also lack a zonal arrangement on this fabric if the blood volume is small and secondary droplets are not always found (Fig. 4a). The shape of smear stains is oval to elongated and a faint smear tailing, which does rarely occur if the blood volume is 0.5µl or less (Fig. 4b), constitutes a criterion for differentiation. The loops of the fabric are not completely soaked with blood so that the underside of the loops are usually free from blood (Fig. 4c). This is not the case in stains from projected blood (Fig. 4d).

2. Pressure stains

Cambric

Pressure stains are oval with irregular edges or finger-like projections (Fig. 5) very distinct from the "bear paw" pattern or "crown-shaped" projections. The fabric is soaked with blood in a homogeneous fashion and the stains lack the zonal arrangement or secondary droplets seen in those from falling droplets.



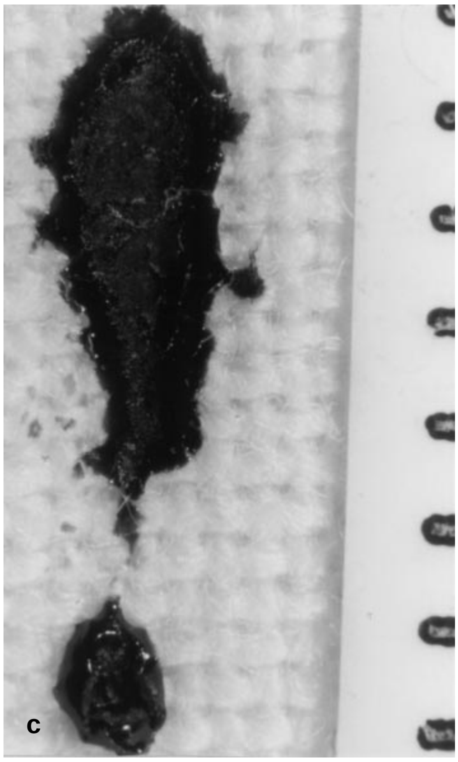


Fig. 3a Contact smear stain on cotton, drop volume 0.5 µl. The lower pole represents the first contact of the finger with the fabric, the smear tailing is located at the upper pole. Scale in mm. **b** Reverse side of the fabric of a contact smear stain on cotton, drop volume 5.0 µl. Scale in mm. **c** Exclamation mark stain from a projected droplet on cotton, drop volume 1.0 µl, impact angle 30°, drop height 50 cm. Secondary and tertiary droplets. Scale in mm

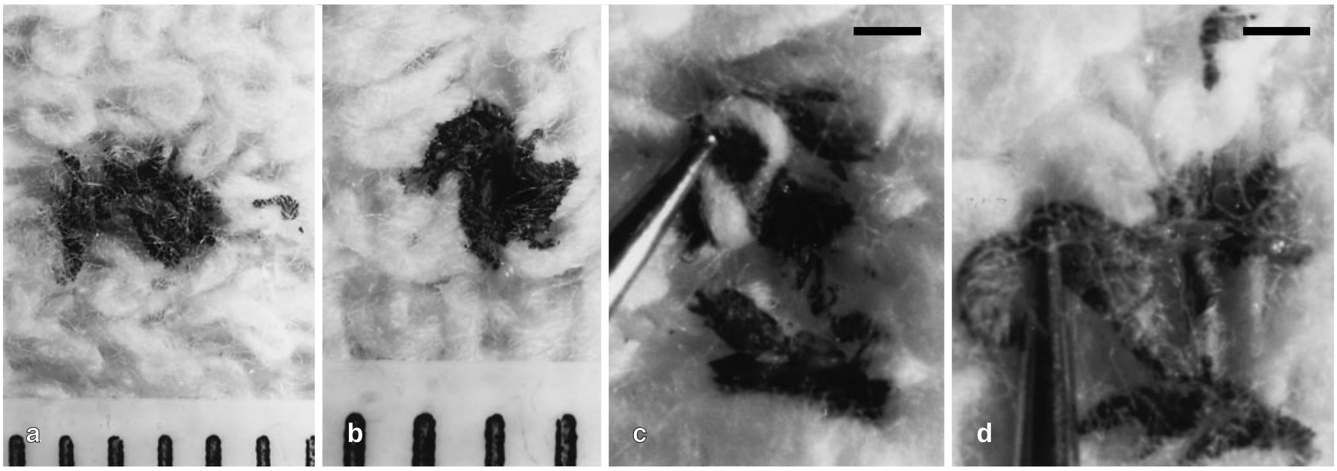


Fig. 4a Stain from a projected droplet on terry cloth, drop volume 1.0 µl, impact angle 30°, drop height 110 cm. The impact site was at the left side opposite to the secondary droplet. The irregular shape is probably due to conductive properties of the fibres. Scale in mm. **b** Smear contact stain on terry cloth, drop volume 0.5 µl. A smear tailing is missing due to the small blood volume. Scale in mm. **c** The terry cloth from Fig. 4b (smear contact stain). The underside of the loop is free from blood. The bar represents 1 mm. **d** The terry cloth from Fig. 4a (stain from projected blood). The underside of the loop is soaked with blood. The bar represents 1 mm

Cotton

The stains are circular to irregular without prominent projections or secondary droplets (Fig. 6a), which are regularly found in stains from falling droplets (Fig. 6b). The ridges of the fabric can frequently be seen whereas the valleys are filled with blood (Fig. 6a). The stains again lack a zonal drying pattern and the reverse side of the fabric is regularly soaked with blood - contrary to stains from falling blood.

Fig. 5 Contact pressure stain on cambric, drop volume 0.25 µl. Scale in mm

Fig. 6a Contact pressure stain on cotton, drop volume 1.0 µl. The prominent projections and secondary droplets seen in Fig. 6b are missing. The soaking is unequal with pale ridges alternating with intense troughs. Scale in mm. **b** Stain from falling droplet (impact angle 90°) on cotton, drop volume 1.0 µl, drop height 90 cm. Scale in mm

Terry cloth

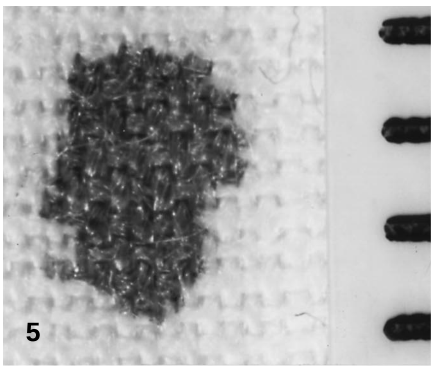
As in the case of smear stains, the irregular surface structure renders a differentiation between contact pressure stains and those from falling droplets difficult. Both are circular to irregular and stains from falling droplets also lack a zonal arrangement or secondary droplets if the blood volume is small. A regularly occurring difference is a paler overall colour compared to similar sized stains from falling blood.

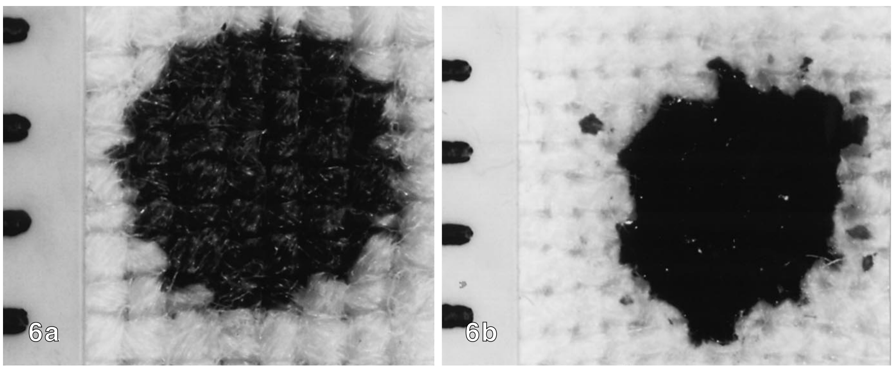
Discussion

The common features described for stains from falling or projected droplets on fabrics are noteworthy because most previous investigations of bloodstain morphology on fabric (e.g. Messler et al. 1981; White 1986) have concentrated on large stains (blood volume 30 µl–1 ml) with the exception of the study by Brinkmann et al. (1985).

For contact stains several common criteria could be identified:

– Asymmetry of the stain (no symmetrical projections). In the case of smear stains, the smearing direction can be established from the decreasing amount of blood in the course of the smear and possibly from the asymmetrical impregnation of the ridges.
– No rhythmicity of the stain pattern (no secondary or tertiary droplets).





- No zonal drying pattern and no horizontal zonal arrangement.
- A clear impregnation of the material. The pressure exerted in producing contact stains leads to a deep infiltration of the fabric, to blood accumulating in the troughs and at the same time to a wider distribution of the blood, whereas the blood from falling or projected droplets commonly tends to lie superficially on the surface of the material. This leads to a blood-soaked reverse side of cambric and cotton in contact stains but not in "dynamic" stains. Furthermore, the deeper infiltration and the wider distribution of the blood results in a paler overall colour and in a smaller blood volume required for contact stains compared to stains of equivalent size from projected blood. The only exception to this impregnation occurred in minute smear stains on terry cloth where the underside of the loops is frequently free from blood but is soaked in stains from projected droplets. The smaller blood volume required for contact stains is most likely insufficient to allow a deep infiltration of the irregular surface of the material.

Several parameters which can influence the appearance of stains were strictly standardized in this study but can vary in actual case work. Variations in the shape of the object (here: finger) and in the time and pressure of contact with the surface and variations in the latent period from deposition of blood to contact with the object can modify the appearance of stains. Different support material of the fabric can change the pattern of impregnation. However, these variable parameters will mainly modify the intensity of the impregnation of contact stains but they cannot produce the characteristic features of "dynamic" forms of stains. Therefore, the differentiation of contact stains from "dynamic" forms can reliably be achieved in most cases. This is a point of major practical importance because suspects are likely to explain microstains on their clothing by contact with the blood after the crime has been committed even if a DNA analysis can demonstrate contact with the victim's blood.

The differentiation of contact stains from "dynamic" forms may be difficult if the fabric has a rough and irregular surface structure. This is especially true for terry cloth, where stains from falling or projected droplets tend to lack the zonal drying pattern and secondary droplets. Furthermore, the differences between contact and "dynamic" stains can be diminished with decreasing size of the stain. Consequently, microstains (blood volume < 1 µl) on a rough surface (e.g. terry cloth) represent the most difficult problem in determining their origin. These cases may only be solved by a microscopical comparison between the stains at hand and experimental stains on the same surface material (Brinkmann et al. 1985; White 1986). A reference collection might be helpful and the reliability of the investigation increases with increasing number of individual stains examined in a case (Brinkmann 1988).

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