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The Reliability of Current Methods of Sequencing Bloodstain

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Abstract Despite the potential value associated with determining the sequence of events from superimposed bloodstain patterns, no formal assessment of the reliability of current methods was found in the published literature. We present here a study of superimposed spatter/transfer patterns on three different substrate surfaces under conditions where the spatter pattern component consisted of a small, medium and large number of stains. This test was done in the absence of perimeter stain effects.

Keywords: Forensic science, Bloodstain pattern, Spatter, transfer, Methods, Classification, Sequence, Error rate.

1 Introduction

It is common for bloodstain patterns at crime scenes to be superimposed [1]. The order in which such patterns are deposited can sometimes be valuable evidence of the timing of the events that took place[1]. The observation, for example, that a bloodied shoeprint impression has spatter stains from a beaten victim on top of the impression indicates that those stains occurred after the shoeprint impression was made. This information would be highly probative if, the defendant claimed he arrived at the scene after the victim had been beaten. Despite the value of this type of evidence, there have been few published studies made of bloodstain pattern sequencing and no standardized methods have emerged.

Determining the sequence of events from bloodstain patterns frequently involves altered patterns. For example, the presence of perimeter stains [2] in a pattern is evidence that more than one event took place with a lapse of time between events [1]. If blood is initially dripped onto a surface and subsequently wiped prior to complete drying, a perimeter ring of staining remains, providing evidence of the sequence of events. If one pattern dries before the second is superimposed, however, sequencing becomes more difficult.

Hurley and Pex [2] concluded that it was difficult to distinguish a dried spatter pattern overlaid by a bloodied shoe impression from a combination of patterns in the reverse sequence. They recommended particular caution when attempting to determine such a sequence from photographs. While Hurley and Pex produced photographs to illustrate their conclusions no controlled experiments were presented. The objective of this study was to formally assess the reliability of current methods for establishing the sequence of superimposed patterns where the first pattern deposited has completely dried.

2 Methods

Two pattern types were selected for this study, namely spatter [3] and transfer [4]. These patterns are commonly encountered at bloodied crime scenes and can often be superimposed. A total of 112 bloodstain patterns comprising superimposed transfer and spatter

1 In the context of this paper a superimposed pattern is the deposition of that pattern on top of an existing pattern.
2 A perimeter stain is an altered stain that consists of the peripheral characteristics of the original stain.
3 A spatter stain is a bloodstain resulting from a blood drop dispersed through the air due to an external force applied to a source of liquid blood.
4 A transfer stain is a bloodstain resulting from contact between a blood-bearing surface and another surface.

stains were prepared, half of which were spatter stains superimposed on transfer stains and half were transfer stains on spatter stains. Fresh human blood, donated by project volunteers, and containing EDTA anticoagulant was used within seven days of drawing. Patterns were created in a controlled laboratory setting at the Minnesota BCA Laboratory. They were created on 16 inch x 16 inch (40 cm x 40 cm) wooden targets. Completed targets were coated with a clear lacquer to prevent deterioration and to assist with biohazard safety. It has been assumed that the clear lacquer coating had no significant effect on the analyst's conclusions.

Transfer stains were created by drawing a blood-soaked cotton glove across the target surface, producing a swipe [5] pattern showing four fingers. Excess blood was removed from the glove before swiping. Spatter stains were created by using a hammer to strike one drop of blood placed on a wooden block in the center of the striking zone. The hammer was propelled by rubber bands and gravity. Bloodstains forming the first applied pattern were allowed to dry thoroughly before the second pattern was superimposed. There were two manipulated variables relating to pattern construction, namely pattern extent (amount of spatter) and target substrate. There were three levels of pattern extent; minimum, medium, and maximum. Category membership was determined by an approximation of the total number of stains in the pattern and the number of stains larger than 1 mm in diameter (Table 1).

Table 1. Scoring system for each DNA profile

Extent	Total Number of Stains	Number of Stains > 1 mm
Minimum	< 50	< 10
Medium	< 50	> 10
Medium	50 – 500	< 50
Maximum	50 – 500	> 50
Maximum	> 500	no criterion

The second controlled variable was the substrate that the pattern was created on. The substrates used were three different hard surfaces, representing varying levels of anticipated identification difficulty, namely: paint (A), wallpaper (B), and chipboard (C). Two coats of white Zinsser 1-2-3 primer were applied to a smooth wooden surface for the paint surface. The wallpaper surface was white Brewster Easy Texture paintable wallpaper (STRIA Pattern 99417F) glued to a smooth wooden surface with one coat of Zinsser 1-2-3 primer applied on top of the wallpaper. The target was rotated prior to pattern creation so that the wallpaper texture ran vertically. The chipboard surface was made from oriented strand board (OSB), which comprises wood fragments bonded in a resin and oriented in random directions. Examples of these target surfaces are shown in Figures 1a and 1b.

Participants chosen for this study were 27 experienced bloodstain pattern analysts with at least 80 hours of training in bloodstain pattern analysis, a minimum of 5 years of BPA experience and had been qualified in court as BPA experts. Analysts were individually invited to participate and were informed that the aim of the study was not to test analyst competency, but rather the reliability of current BPA methodology. They were also informed that their participation and responses would remain anonymous. Materials were only sent to analysts after they had indicated a willingness to participate.

Each analyst received a unique set of 3 or 4 sequencing targets and a response sheet for each target. A number was placed at the top of each target that identified which target corresponded to each response sheet and also indicated the pattern alignment during pattern construction. The response sheet stated: "This sample has both a transfer and a spatter pattern on it. You are asked to determine the sequence in which these two patterns have been applied. Please choose ONE of the following:

- Spatter first followed by transfer
- Transfer first followed by spatter
- I cannot determine which pattern occurred first

After completing the survey, analysts emailed or posted their responses to an independent third party. All materials and responses were returned to experimenters via the third party to ensure they remained anonymous. Each possible variable combination (sequence order X substrate X extent) was replicated a minimum of 5 times.

3 Results

Of the 112 samples distributed to participants, responses to 104 were received. These comprised 50 combinations of spatter stains superimposed on transfer stains and 54 instances of transfer stains on

5 A swipe pattern is a bloodstain pattern resulting from the transfer of blood from a blood bearing surface onto another surface, with characteristics that indicate relative motion between the two surfaces.

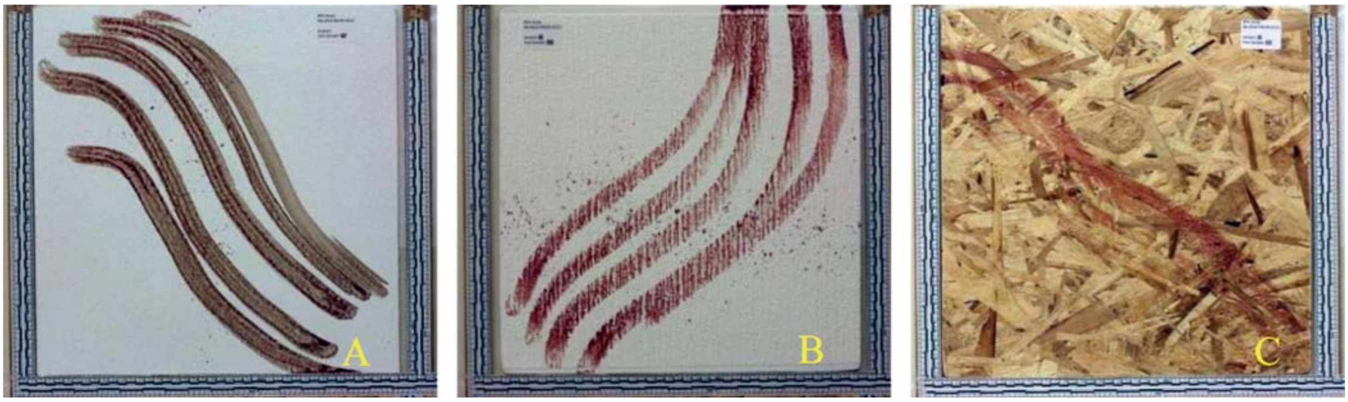

Fig 1a. Example of patterns created on paint (A), wallpaper (B), and chipboard (C) surfaces.

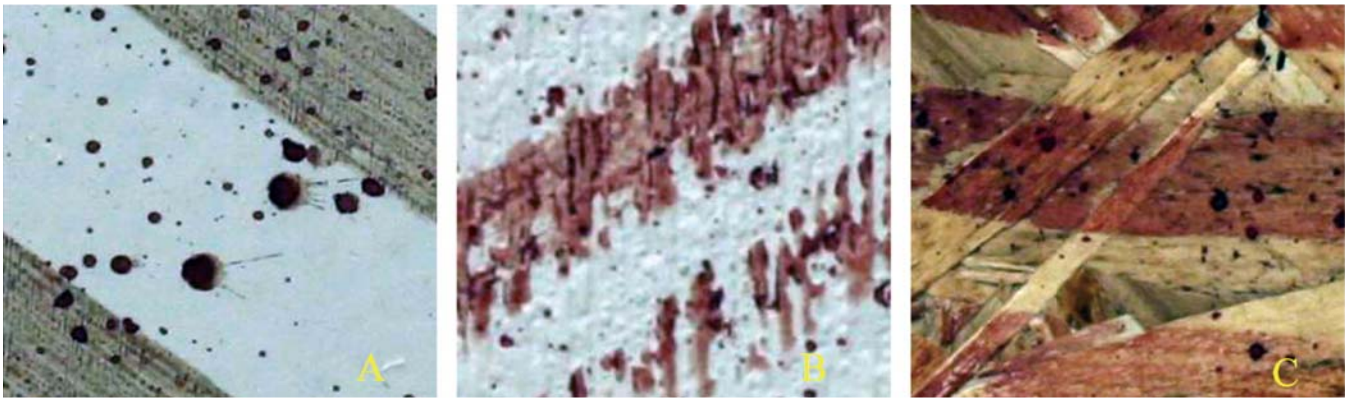

Fig 1b. Close-up images of superimposed patterns on paint (A), wallpaper (B), and chipboard (C) surfaces.

spatter. Of the 104 conclusions given, over half (52.9%) were recorded as inconclusive meaning they could not determine which pattern occurred first, 32.7% correctly assigned the sequence and 14.4% gave an incorrect interpretation.

Figure 2 shows a breakdown according to the original pattern combination presented. It is apparent from these results that there was a marked difference in the response of analysts to the two pattern sequences they were presented with. Where spatter stains were deposited on top of transfer stains, 48% of the patterns were correctly sequenced, whereas for the reverse sequence this figure dropped to 19%. There was a corresponding increase in the proportion of inconclusive responses from 40% to 65%.

These results appear to show that when spatter stains are deposited on transfer stains, analysts were more willing to give an interpretation and those interpretations are more likely to be correct. For those targets that analysts were prepared to make an interpretation, 80% were correct when the pattern was spatter on transfer, but only 53% were correct if the transfer followed the spatter. The difference in response between the two pattern combinations was statistically significant, X^2 (2, N=104)=5.26, p=0.004. Overall, the effect of substrate on correct responses was not significant, although Figure 3 shows a higher proportion of correct

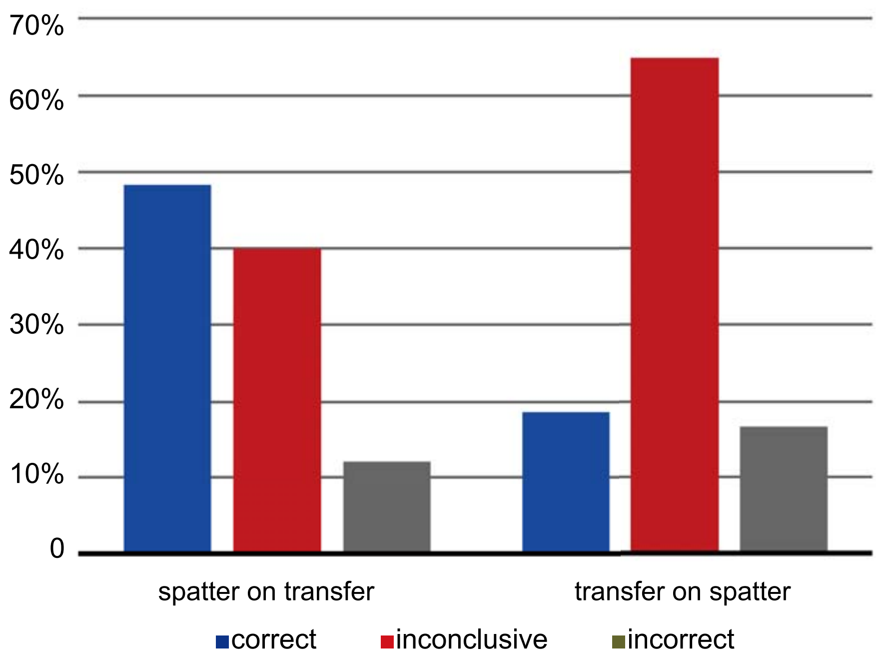

Fig 2. Accuracy in the determination of pattern deposition sequence.

interpretations for painted surfaces when the pattern combination was spatter on transfer.

Figure 4 shows that the number of incorrect interpretations increased and the number of inconclusive responses decreased slightly, as the extent of spatter increased in both spatter on transfer and transfer on spatter combinations. Those targets that had a spatter pattern with many stains (i.e., maximum extent) overlaid with a transfer pattern gave the highest number of incorrect interpretations. No errors were made, when the spatter pattern was at its minimum extent although 70% of the responses were inconclusive. However, the overall effect of pattern extent was significant, $X^2(4, N=104)=9.71$, $p=0.046$.

4 Discussion

Because the bloodstains in this study were allowed to dry completely between the two depositions, there were no perimeter stain effects to give clues as to the order of deposition. In the absence of this, it is possible that the analysts' attention was drawn to the intensity of the individual stains, with the more intense stains reckoned to be the more recent of the two depositions. Spatter stains deposited on transfer stains will generally

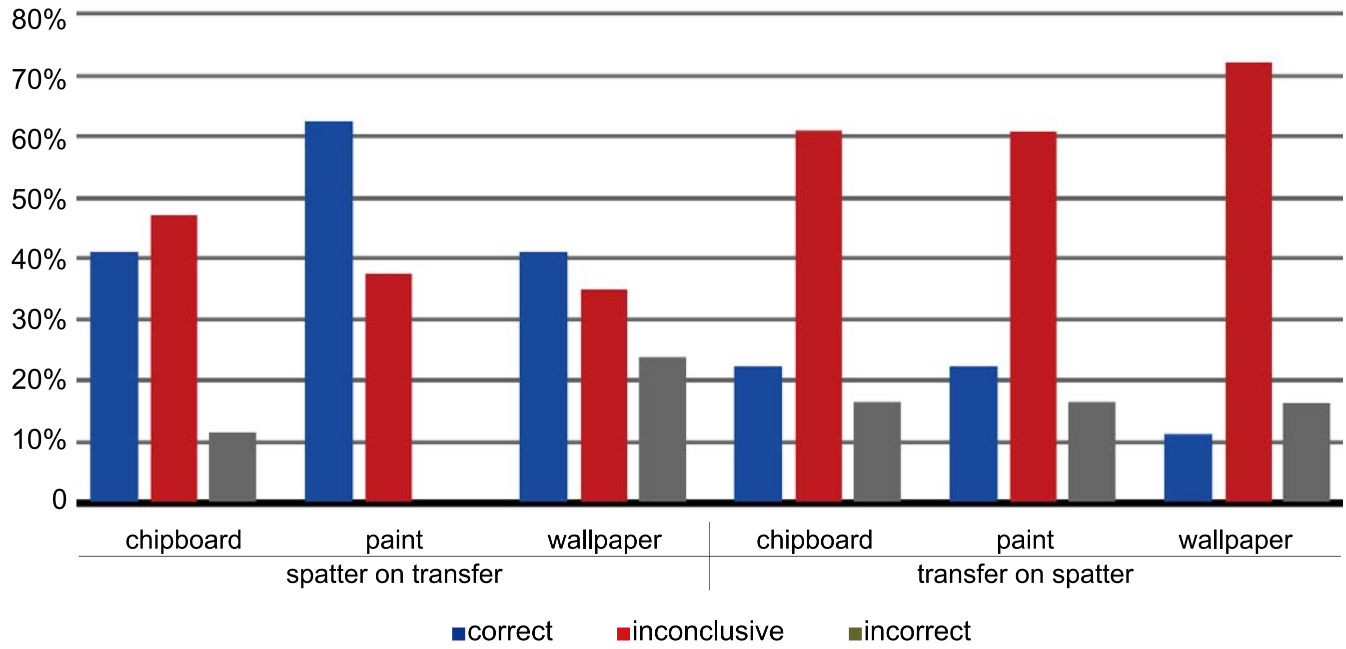

Fig 3. Effect of substrate on sequencing conclusions.

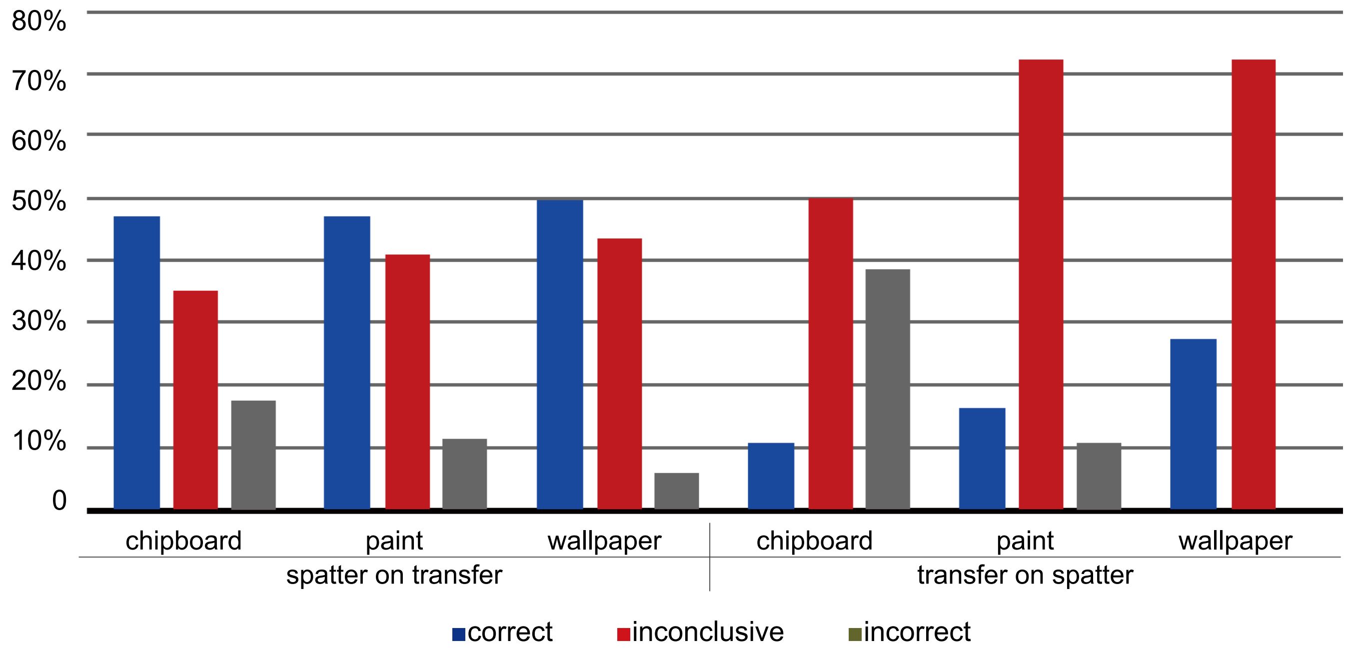

Fig 4. Effect of pattern extent on sequencing conclusions.

appear darker in color, suggesting they have been deposited last (e.g. Figure 5). However spatter stains deposited under transfer stains may also appear darker in color, especially if the transfer stain is a thin smear (e.g. Figure 6).

Under these circumstances the spatter stains may also give the impression they have been deposited on top of the transfer stain. This may also account for the fact that patterns with welldefined, maximum extent spatter overlaid by transfer stains had the highest proportion of incorrect conclusions. Where the spatter stains were fewer in number these incorrect interpretations were not evident. The number of incorrect conclusions increased as the extent of spatter increased in both spatter on transfer and transfer on spatter, while the number of inconclusive responses decreased slightly. This suggests that an increase in the number of datum points in the pattern is giving an increasingly false sense of confidence for an analyst when making a judgment about sequencing.

5 Conclusions

This study on superimposed patterns showed that, for the current sequencing methods and in the absence of perimeter stain effects, the chances of incorrectly concluding the order of deposition in a spatter/ transfer pattern combination is approximately 12% where spatter stains are deposited on top of transfer stains and 17% for the reverse sequence. These results demonstrate the need for more reliable methods for bloodstain pattern sequencing and suggest that extreme caution should be exercised in making such determinations.

In general, analysts were reluctant to draw a firm conclusion in approximately half the samples and incorrectly concluded the sequence of patterns in approximately 12% of pattern combinations where spatter stains were deposited on top of transfer stains and 17% for the reverse sequence. The pattern substrate was not found to be a significant factor in the accuracy of sequencing. There was limited evidence to suggest that a more extensively spattered pattern, in combination with a transfer pattern may increase the incidence of misinterpretation of sequence.

Acknowledgements

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References

[1] Kish, P.E., T.P. Sutton, and S.H. James, Principles of Bloodstain Pattern Analysis: Theory and Practice 3ed. Boca Raton, 2005: CRC Press: 576.
[2] Hurley, N.M. and J.O. Pex, Sequencing of Bloody Shoe Impressions by Blood Spatter and Blood Droplet Drying Times. International Association of Bloodstain Pattern Analysts News, 1990, 6(4): 1-8.

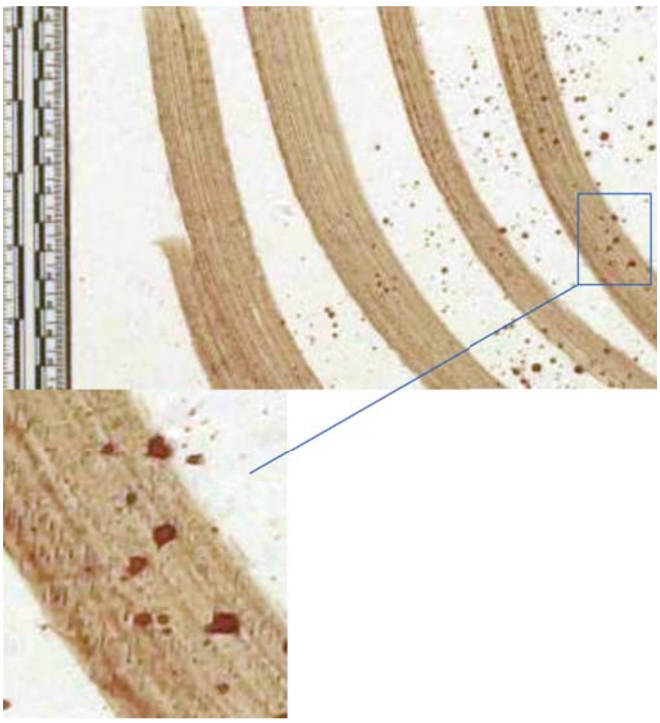

Fig 5. Spatter stains deposited onto a transfer pattern.

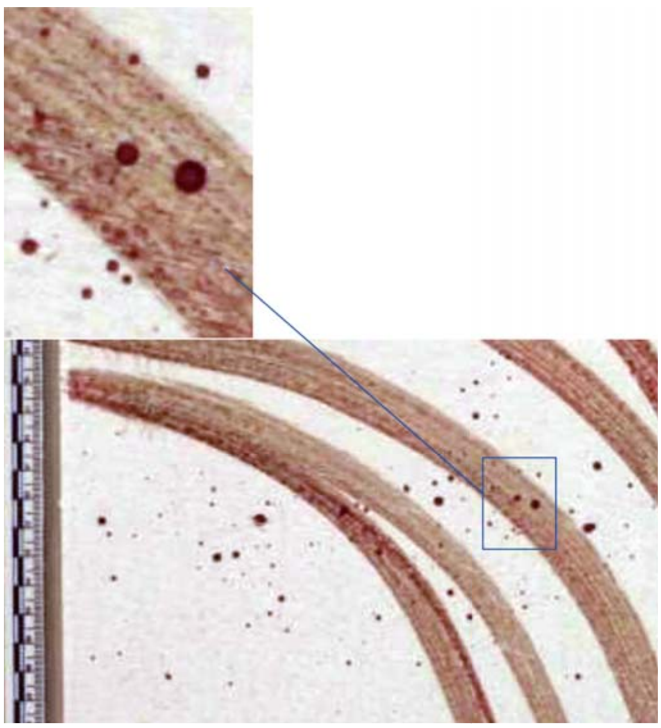

Fig 6. Transfer pattern deposited onto spatter stains.