

TECHNICAL NOTE**CRIMINALISTICS***J Forensic Sci*, July 2017, Vol. 62, No. 4

doi: 10.1111/1556-4029.13298

Available online at: onlinelibrary.wiley.com

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The Reliability of Swipe/Wipe Classification and Directionality Determination Methods in Bloodstain Pattern Analysis

ABSTRACT: Swipe and wipe are types of transfer patterns commonly encountered at bloodied scenes. So far, there have been little published data on the reliability of evaluating these patterns. In this study, 36 bloodstain patterns were randomly assigned to 12 analysts in three separate trials, and the analysts were required to evaluate the pattern type and directionality. The results revealed that correct classifications of patterns type were problematic, with an overall error rate of 32%. Wipes created from wet bloodstains were the most difficult to identify due to the absence of signs of alteration. The directionality of swipes made with a gloved finger had a 100% success rate; however, for swipes made with cloth, the analysts mistook the direction in nearly every case, which is of significant concern, considering these are common patterns at crime scenes. This study suggested there is a need for revising the current protocols for interpretation of these pattern types.

KEYWORDS: forensic science, bloodstain pattern, swipe, wipe, methods, classification, directionality, reliability

Swipe and wipe patterns are types of transfer patterns that are commonly encountered at bloodied scenes. Transfer patterns occur when blood is deposited onto a surface as the result of the physical contact between a wet bloodstained source and a non-bloodied object (1). These patterns can be examined to provide information on the movements and activities made by the assailant or victim involved in the crime scene (2–4).

Unlike other transfer patterns, which are produced by simple direct contact, swipe and wipe patterns involve movement of either one or both of the two contacting surfaces. The difference between swipe and wipe patterns is based on the initial location of the blood prior to the contact between the two surfaces. The distinction between them is as follows (5):

A wipe pattern is “An altered bloodstain pattern resulting from an object moving through a pre-existing wet bloodstain.”

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.”

In this study, we will also use the term “smear” to mean either a wipe or a swipe.

Swipe marks are often associated with movement of blood-soaked hair, bloodied hands, or items of clothing at a crime

scene (6). They indicate movement, the direction of which can sometimes be determined. Gardner (7) described five identifying characteristics of swipe patterns that can be used to determine which side of the pattern is the contact edge and which side is the departure or lift-off edge and therefore the direction of the pattern. These were “irregular demarcation,” “feathered demarcation,” “striations within the body of the stain,” “decreasing volume in the body of the stain,” and “welling of blood in a stain boundary.” Commonly, the contact point is associated with the characteristic of irregular demarcation, whereas for the departure end, it can be characterized by one or more of the other characteristics. Gardner concluded that the “combination of an irregular demarcation with an evident-diminished volume on the opposite side of the stain would appear to be the most valid combination of characteristics for defining the direction of motion of a swipe pattern.” Using this method in a blind trial, he correctly identified the direction of motion in 86% of 22 unknown patterns.

Wipe patterns involve two steps. First, blood is deposited, and second, contact occurs between this blood and another surface, with some movement and prior to the blood drying. Such patterns can therefore sometimes be used to indicate the sequence of events. According to Wonder, the lift-off edge for wipe patterns often appears darker than the contact edge, and the opposite occurs for swipe patterns (8). This type of pattern is commonly produced by fingers, hands, and fabrics at crime scenes. Although wipe patterns share some characteristics with swipe patterns, including feathering, striations, diminished volume, and blood accumulations, they may be distinguishable from swipe patterns if there is evidence of a pre-existing blood volume or if the pattern contains perimeter stains. This is due to the fact that wipe patterns involve the alteration of a pre-existing blood source; therefore, any original blood volume present will

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Received 6 Jan. 2016; and in revised form 30 May 2016; accepted 10 July 2016.

be altered by the displacement caused during the motion, especially if that motion is some time after the deposition of blood.

For those occasions when correctly classifying a stain as a wipe or a swipe is of critical evidential value, it is important to know how reliable this distinction can be made. However, there appear to be no published studies that have considered this. Furthermore, despite cautionary notes by authors about predicting direction of motion in smeared stains, there is a lack of data to support this. The study presented here has been designed to begin to address these issues.

Methods and Materials

Porcine blood was used for these experiments. It was collected fresh from a local abattoir into clean glass bottles containing 7 g EDTA per liter of blood. The blood was carefully and thoroughly mixed on collection and stored at 4°C until required. It was warmed to 37°C prior to use in pattern creation.

Two contact materials (cotton cloth and vinyl glove) were chosen, as representatives of porous and nonporous surfaces, respectively. It has been suggested in the literature that porous materials may cause blood droplets to rupture, giving characteristic features such as irregular shapes and spiny edges (9). Therefore by using porous and nonporous surfaces, the success rate for pattern type and directionality determination can be compared.

Sets of swipe patterns were created by placing three drops (approximately 0.5 mL) of blood on a piece of clean cotton cloth or on three fingers of a vinyl-gloved hand which was then swiped across a section of plain white cardboard in one motion. Three replicates of each were prepared. To create wipe patterns, a drop of blood (approximately 0.5 mL) was placed in the middle of a section of plain white cardboard. The blood was wiped off in one motion with a piece of clean cotton cloth or the finger of a vinyl-gloved hand. One set of three replicates was prepared immediately following deposition and a second set after the blood had dried for 4 min at room temperature. The choice of this 4-min interval was based on a side experiment, where the perimeter ring only started to develop by the end of 3 min.

The above preparation yielded a total of 18 bloodstain patterns all created by the same operator and were repeated in both left to right and right to left directions, making a total of 36 patterns. These patterns were photographed using a Canon PowerShot SX10 IS and were stored as standard JPG format at 10 Mega Pixels (3648 × 2736) and were color-printed on 80 gsm, 297 × 210 mm, A4, OfficeMax® multipurpose plus copy paper, using Konica Minolta color printer, model Bizhub C451. These patterns were then randomly assigned to 12 analysts in three separate trials in such a way that each pattern was examined six times by different analysts. This meant that each analyst received half of the total number of samples over the course of the study. A total of 216 examinations were made. For each examination, the analyst was first asked to classify the pattern as a wipe or a

swipe and second to give an opinion as to the direction of motion. The analysts were given an option for an “inconclusive” answer and were requested to provide a reasoning for their response. This option avoided the problem of forcing the analyst to pick an answer in situation where the pattern did not possess sufficient characteristics to draw a conclusion.

The analysts chosen for this study were all experienced case-working forensic scientists, qualified in bloodstain pattern analysis working in a quality system that includes yearly proficiency testing. Participants were not required to follow a prescribed method for examining the test materials in this study. Rather, they were expected to apply their knowledge and skills acquired from basic and advanced BPA training programs and experience gained over years of examining bloodied crime scenes and forensic exhibits in the laboratory and giving testimony in court. Hence, the study was designed to be a test of methods currently employed by bloodstain pattern analysts.

Results

Swipe/Wipe Pattern Classification

Analysts were asked to inspect each pattern and classify it as either a wipe or a swipe. Table 1 gives the results. This trial showed that under the conditions of this experiment, approximately one-third of the patterns were misclassified. About 5% of the classifications were inconclusive. Analysts' answers were judged to be inconclusive if they gave no answer or indicated that their classification was a guess.

Analysts were more successful in classifying a swipe pattern (83%) than a wipe pattern (53%).

A breakdown of the data for the wipe patterns shows that the error rate depended to a large extent on the type of wipe pattern created (Fig. 1). Eighty-six percent of patterns created after some drying were correctly classified, whereas only 19% of patterns created with no drying were correctly classified.

Figure 2 shows an example of a wipe pattern with no drying (Pattern A11) and a swipe pattern (Pattern A25) both made using a fabric surface. These two patterns are very similar in appearance. Five of the six analysts who were given Pattern A11 mistakenly identified it as a swipe pattern, with one inconclusive result. Only one of six analysts given Pattern A25 mistakenly identified the pattern as a wipe. These results suggest that when analysts are confronted with a smear of blood that shows no sign of alteration, they tend to classify it as a swipe.

Evaluation of the influence of material used in bloodstain pattern creation on classification error shows a much smaller effect. Of the 70 patterns misclassified, 59% were patterns made with a gloved finger and 41% were made with a fabric surface. While it appears that fabric-related smears may be more reliably classified, the fact remains that the overall misclassification rate is high regardless of the material used to create the pattern.

TABLE 1—Classification of pattern type within the swipe/wipe pattern set.

	Glove Swipe	Cloth Swipe	Glove Wipe Following Partial Drying	Glove Wipe With No Drying	Cloth Wipe Following Partial Drying	Cloth Wipe with No Drying	Total
Correct Classification	28	32	27	7	35	7	136
Incorrect Classification	5	4	9	27	1	24	70
Inconclusive	3	0	0	2	0	5	10
Total	36	36	36	36	36	36	216

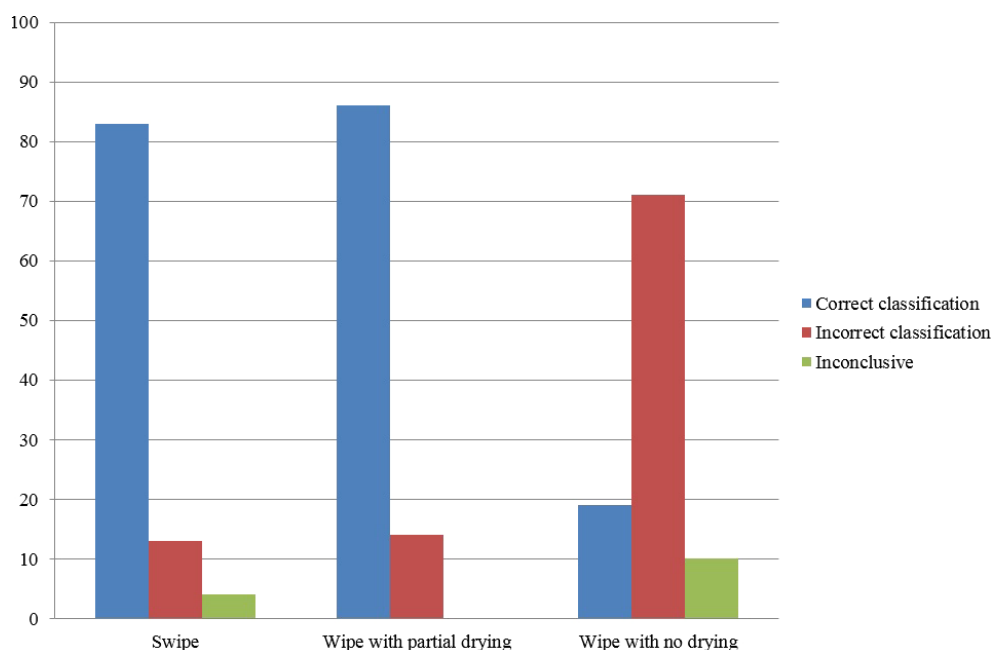


FIG. 1—Accuracy rates for the classification of swipe and wipe patterns. [Color figure can be viewed at wileyonlinelibrary.com]



FIG. 2—Bloodstain patterns A11, a wipe pattern, and A25, a swipe pattern. Both patterns were created using a fabric surface. [Color figure can be viewed at wileyonlinelibrary.com]

It was thought that wipe patterns showing signs of perimeter staining would have had a 100% correct classification rate, as the presence of a perimeter ring is only applicable for wipe patterns. A review of individual results showed that one pair of test patterns (patterns A1/A2) was responsible for nine of 10 misclassifications. One of this pair (A1) is shown in Fig. 3 alongside an example of a wipe pattern that was correctly interpreted in every instance (Pattern A26). Although the perimeter stain is less distinct in Pattern A1 than in A26, it is nevertheless recognizable.

Swipe/Wipe Pattern Directionality Determination

In this part of the study, analysts were asked to inspect the same patterns as before and determine the direction of motion that had caused the pattern. Table 2 gives the results. This trial showed that under the conditions of this experiment, directionality was incorrectly assigned in approximately one-third of the patterns. About 2% of the determinations were inconclusive.

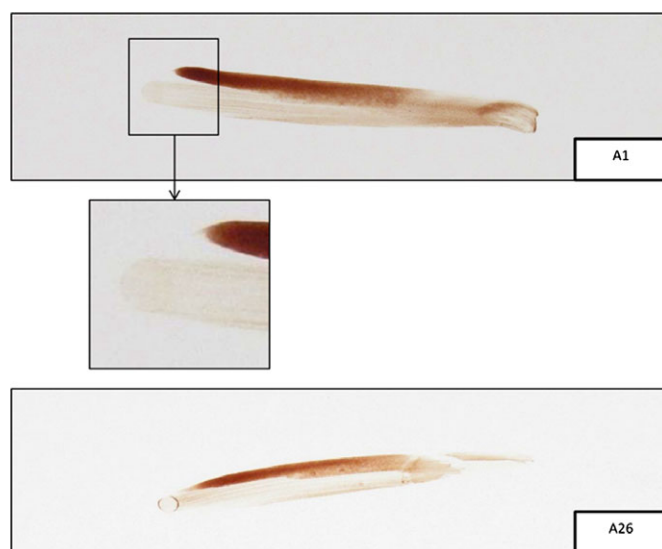


FIG. 3—Examples of wipe patterns created with a gloved hand, following partial drying of the original bloodstain. [Color figure can be viewed at wileyonlinelibrary.com]

For swipe patterns, analysts showed only a slightly better than 50% chance of correctly determining the direction of motion. Wipe patterns proved somewhat easier with the directionality determined successfully in 72% of these patterns.

Evaluation of the influence of the material used in the creation of the patterns shows that when the stain was made with a gloved finger, the directionality was successfully determined in 87% of the patterns, whereas the corresponding rate for smears made with fabric was 43%.

A ranking of accuracy rates for the various pattern creation methods shows that directionality was reliably determined for three methods in particular (Fig. 4). The directionality of glove swipes was correctly determined in every case, while that of

TABLE 2—Determination of directionality within the swipe/wipe pattern set.

	Glove Swipe	Cloth Swipe	Glove Wipe with Partial Drying	Glove Wipe with No Drying	Cloth Wipe with Partial Drying	Cloth Wipe with No Drying	Total
Correct Directionality	36	1	24	34	35	10	140
Incorrect Directionality	0	34	12	2	1	23	72
Inconclusive	0	1	0	0	0	3	4
Total	36	36	36	36	36	36	216

cloth wipes made after partial drying and glove wipes made prior to drying gave success rates of 97% and 94%, respectively.

A very high accuracy rate was expected for the wipe patterns following partial drying as the perimeter staining provides a clear indication of the starting point of the motion. This was the case for the wipes made with fabric, but for wipes made with a gloved finger, the results were surprising. Despite the presence of a perimeter stain, the directionality of glove wipes was correctly deduced in only 67% of the patterns of this type. As was the case for pattern classification, the pattern pair A1/A2 accounted for 12 of the 14 errors. It is possible that analysts mistook the unusual shape of what was actually the lift-off end of this particular stain as perimeter staining and did not recognize evidence of faint but true perimeter staining at the opposite end (refer to Fig. 3, Pattern A1).

Another cause for concern was that analysts almost always mistook the direction of swipes made with fabric (3% success) and to a lesser extent fabric wipes made with stains with no initial drying (28% success).

Observations of the swipe patterns and those wipe patterns made without initial drying showed that there was always a higher volume of blood present at the start of the smear for patterns created by a gloved finger. On the other hand, the volume of blood tended to be higher at the departure end for patterns created by cloth. The nonabsorptive surface of the gloved fingers was apparently not completely effective in displacing the wet blood and left behind significant proportions at the start of the smear while producing a tapered and feathered end. The more absorptive fabric surface on the other hand has been effective in

both reducing the quantity of blood in the smear and displacing it across the smear. Figure 5 shows two bloodstain patterns, a swipe and a wipe following drying that were created by a gloved finger with direction of right to left. Both patterns show that there is a higher volume of blood at the starting point with a decreasing intensity of blood along the direction of travel. Furthermore, the blood patterns have a tapering shape with a feathered margin at the lift-off end. Figure 6 illustrates a swipe and a

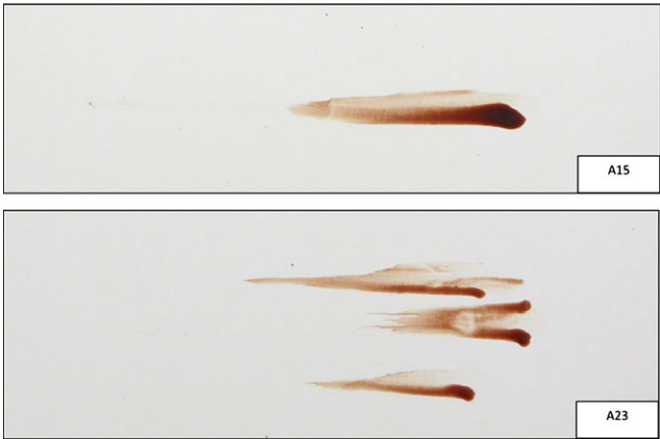


FIG. 5—Bloodstain patterns A15 and A23. Both patterns are created by glove with directionality of right to left. Pattern A15 was a wipe pattern without drying, and A23 was a swipe pattern. [Color figure can be viewed at wileyonlinelibrary.com]

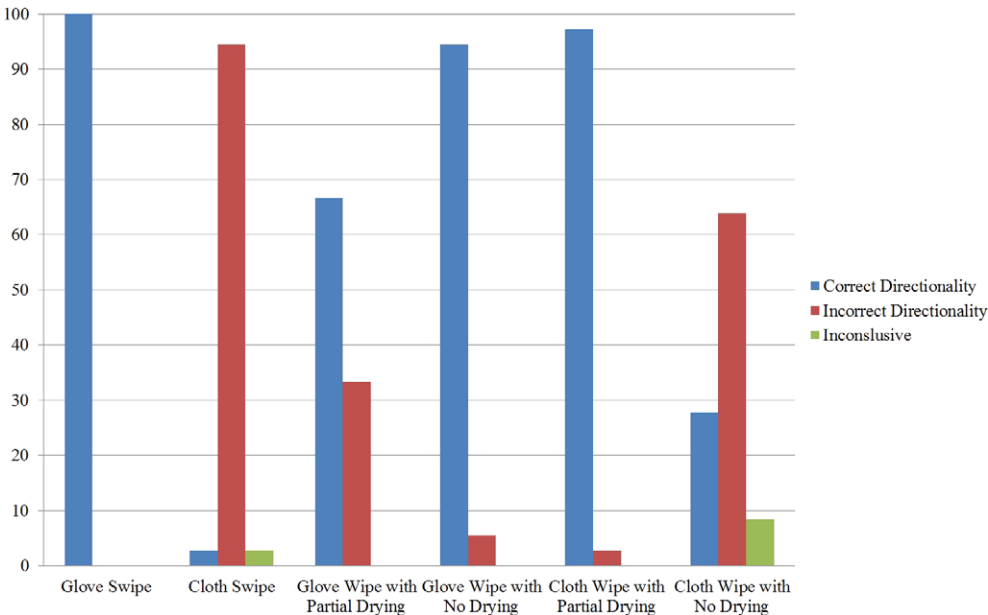


FIG. 4—Accuracy rates for the determination of directionality of swipe and wipe patterns. [Color figure can be viewed at wileyonlinelibrary.com]



FIG. 6—Bloodstain patterns A19 and A34. Both patterns were created by cloth in the right to left direction. Pattern A19 is a wipe pattern without drying, and A34 is a swipe pattern. [Color figure can be viewed at wileyonlinelibrary.com]

wipe pattern with drying, created by cloth, also with a direction of right to left. Unlike the previous two bloodstain patterns, the starting point of the contact side does not show a higher volume of blood. Instead, there is an accumulation of blood at the margin of the lift-off end. Furthermore, the contact end of the smears shows feathered margins.

It is suspected therefore that some analysts determined the direction of the smear using the relatively higher volume of blood as an indicator for the starting point of the pattern and/or the more lightly feathered end as an indicator of the finishing point of the pattern. This could account for the higher degree of success in determining the direction of finger smears than fabric smears when there were no drying effects to aid interpretation.

Conclusions

Correctly classifying wipe and swipe patterns of the type created in this study was problematic with an overall error rate of 32%. This was particularly true for wipe stains created before the wet bloodstain had had a chance to start drying. Such stains did not necessarily show any signs of alteration. Analysts tended to conclude these were in fact swipes. This is perhaps not surprising as the mechanism of pattern formation of wipe stains under these conditions is similar to that of swipe stains. While the classification of wipe patterns created following partial drying was much more reliable, it was not without error. The misclassification in this study appears to be a failure to observe subtle evidence of perimeter staining.

Reliable classification of a wipe pattern is achievable if it recognized that it is an altered pattern and there is clear evidence of the original pattern such as perimeter staining. The patterns used in this study were essentially single-stain patterns. Patterns comprising several stains may also provide additional information to aid classification. For example, the presence of smears within an otherwise unaltered pattern may be evidence that wiping has occurred.

The results of this study suggest the following protocol for wipe/swipe classification:

- A smear pattern is a wipe if there is clear evidence of alteration of the original pattern, such as partial disruption and displacement of blood and/or perimeter staining

- If such evidence is absent, the pattern should be classified as a swipe or a wipe.

Note under this protocol, that there is no basis for unambiguously identifying a swipe. It could be argued that there are circumstances under which it is virtually impossible to create a wipe pattern without the remnants of the original pattern being visible. Under these conditions, the absence of evidence of a pre-existing pattern may be a reliable basis for the classification as a swipe. The collection of data required that address this argument is beyond the scope of this study.

The results of this study also suggest that the determination of directionality is difficult to do reliably with an overall error rate of 33%.

Fingermarks appear to offer hope of a reliable determination of direction of smearing. The directionality of swipes made with a gloved finger in this study was successfully determined in every test in the study. However, when fingers were used to create a wipe pattern, the success rate dropped to 67%. Success in determining the direction of smears made with a fabric surface was considerably less. When there was evidence of stain alteration by drying, the direction of a wipe was quite reliable (97%) but where no evidence of a pre-existing stain was present, this rate was less than 30%. In fact, for swipes made with cloth, analysts mistook the direction in nearly every case, which is of significant concern considering these are common patterns at crime scenes.

In this study, analysts appeared to place great reliance on the presence of a feathered margin as an indicator of the lift-off end of the smear, combined with an assumption that a diminished volume across the stain will be in the direction of the smearing. These assumptions proved generally reliable for the gloved finger smears but were not valid for the smears made with the more absorptive fabric surface.

This study has demonstrated the general unreliability of current methods for the determination of direction of motion in smeared stains, in particular for swipes from bloodied fabric. However, there does appear to be potential to reliably determine the direction of a wiped stain where the clearly visible perimeter stain indicates the start of the motion. Smears made with fingers should also be discernable especially when there are parallel smears from more than one finger present in the pattern. These smears are characterized by an ending that is often tapered and feathered.

The guidelines offered by Gardner for the determination of directionality in swipe stains, namely “a combination of an irregular demarcation with an evident-diminished volume on the opposite side of the stain,” do not appear to be sufficient for the fabric swipes in this study. In Gardner’s terms, these fabric swipe patterns were characterized by a feathered demarcation at the contact end and a welling of blood at the lift-off end. There appears, therefore, to be some way to go in developing a reliable method for the range of smear patterns likely to be encountered in forensic investigations.

In the meantime, the following protocol for the determination of directionality in wipe and swipe stains is suggested:

- Where there is clear evidence of partial disruption of an original stain, such as perimeter staining, the direction of smearing can be deduced from the direction of displacement of blood away from the original stain
- Where there is clear evidence of smears made by fingers, such as two or more parallel smears, the direction of smearing can be deduced by identifying the lift-off end as a tapered and probably feathered end.

This use of this protocol would leave the directionality of many smear stains undecided, but until such time as new methods are developed, this may be the most prudent approach.

The current study has generated some initial data on which to base an assessment of the reliability of pattern classification and directionality determination for swipe and wipe patterns. To solidify these findings, more work is required including extending the range of recipient surfaces and assessing methodology across a wider group of analysts. Before concluding that distinguishing between swipes and wipes and determining their direction are limited to a narrow range of stain conditions as suggested by this study, the search for better methodology should continue. This search is likely to benefit by including a closer look at the dynamic mechanism of the formation process of such stains.

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