Latent Print Processing of Glassine Stamp Bags Containing Suspected Heroin: The Search for an Efficient and Safe Method

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Comments
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Abstract: A three-part study was designed to find the safest and most efficient method of processing glassine stamp bags containing suspected heroin while preserving the qualitative properties of the substance. Gravimetric analysis was also conducted to determine whether selected processing methods add weight to clean stamp bags. Qualitatively, the processing methods chosen for this study did not eliminate heroin from the samples. Results of a blind evaluation of developed latent prints indicate that under the controlled conditions of this study, magnetic powdering yielded the most “of value” latent fingerprints. However, because previous research has shown that magnetic powder is most effective a short time after fingerprint deposition (which was the case in this study), this conclusion should be regarded as tentative until longer times between deposition and recovery are studied. Gravimetrically, the processing methods used in this study add an amount of weight to the bags that is within the uncertainty of measurement for this laboratory.
Introduction

According to Overdose Free PA, which collects and analyzes data from medical examiners’ and coroners’ offices across Pennsylvania, Allegheny County saw 650 reported overdose cases in 2016. Of the 650 reported cases, heroin was found in 330. The data for 2017 is not complete, but at this time, the number of overdose deaths with heroin present has seen a slight decline to 287 cases, or 39.0 percent of the overdose deaths, whereas in 2016 it was found in 50.8 percent of the cases [1]. Since 2014, there has been a notable increase in fentanyl submitted to the Allegheny County Office of the Medical Examiner (ACOME) Forensic Laboratory Division as suspected heroin. Fentanyl has been seen both with and without heroin and now constitutes a significant portion of the casework submitted for analysis by the drug chemistry unit. More potent fentanyl-related substances have also been encountered such as carfentanil and 3-methylfentanyl. In addition, novel fentanyl-related substances (methoxyacetylfentanyl, cyclopropyl fentanyl, etc.) and other novel opioids (U-47700, U-48800, etc.) have also been encountered in casework. Many of these suspected heroin cases, which are received packaged in glassine stamp bags1, are first submitted for latent print processing.

Prior to the completion of this study, cases involving glassine stamp bags suspected to contain heroin were processed in the latent prints section of the ACOME according to a procedure that required the scientists to transfer the powder out of each bag. The tape holding the bags closed first needed to be carefully cut with a razor blade while protecting the integrity of the bag. The contents were then transferred into a clean, numbered, prefolded glassine packet, which was labeled with pertinent case information. The empty stamp bag was then sprayed with ninhydrin and placed in a fingerprint development chamber under controlled heat and humidity conditions. This method was time consuming, posed a safety risk to scientists, and created a potential for loss of the drug because of static and the possibility of becoming airborne.

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1 Glassine bags are also commonly used for postage stamps and are made out of a material similar to the wax paper sometimes used to wrap food.
Submissions of glassine stamp bags are frequently received as multiple bundles (10 bags per bundle) and bricks (50 bags per brick). At the ACOME, any item of a quantity of 50 or more is subjected to a 10-percent black box sampling plan for case management purposes. Even with a sampling plan in effect for large submissions, working a case to completion may take anywhere from two hours to a full working day.

For the purpose of case management and increased scientist safety, alternate methods were explored for the laboratory to continue processing stamp bags without these burdens and hazards. Although personal protective equipment (such as gloves, face masks, and eye protection) reduces the risk of accidental exposures [2], a procedure that no longer involved emptying the bags would optimize working conditions.

An important component of the study was the selection of the latent print development methods for testing. The previous literature and experimentation regarding which latent print processing methods produce the best results on glassine bags is sparse. It was therefore necessary to draw on previous internal studies regarding different combinations of processes and general knowledge of the properties of glassine bags and fingerprint residue, while taking into consideration the practicality of the methods. Because glassine bags are a semiporous surface, the generally suggested methods of processing range from cyanoacrylate fuming and powdering, a typical method for nonporous surfaces like glass, to DFO and ninhydrin processing, which are typical methods for porous surfaces like paper and cardboard. A survey of 28 laboratories [3] found that all of the laboratories used some variation of ninhydrin for case work, and 86 percent of laboratories used some formulation of DFO. Testing these two reagents, which can also be used sequentially, and additionally magnetic powder, would therefore provide information for processing methods that are already commonly used by many laboratories.
Materials and Methods

Study I: Qualitative Drug Analysis of Ninhydrin-Processed Stamp Bags

An initial study was conducted to determine whether the use of ninhydrin and a humidity chamber on glassine stamp bags would reduce the amount of heroin in the bags. In the presence of water, heroin breaks down into 6-monoacetylmorphine (6-MAM), and then into morphine. Thus, the use of a humidity chamber may be an issue. The schedule of controlled substances in Pennsylvania [4] specifies that powder containing any amount of heroin is illegal (in other states, laws may vary). Therefore, to be of any practical concern, the reduction would have to be so complete that heroin would be eliminated from the sample.

Samples were prepared in a 9:1 chloroform:methanol solution with 0.0125 mg/mL C24 (tetracosane) as an internal standard. Powder from 23\(^2\) seized drug bags was mixed in and analyzed pre- and post-ninhydrin processing using the area under the curve from gas chromatography-flame ionization detection. Additional glassine bags were prepared to mimic fentanyl samples observed in the laboratory. These bags contained fentanyl (7.5% by weight), quinine, and sugar.

The ratio of heroin to 6-MAM was examined to determine whether the ninhydrin and fingerprint development chamber [Model FDC185 Fingerprint Development Chamber, Sanyo Gallenkamp (now Weiss Technik, Loughborough, U.K.)] use had any effect on the heroin samples.

Studies II and III: Evaluation of Latent Print Processing Methods and the Gravimetric Analysis of Empty Stamp Bags

The second and third parts of the study were carried out in tandem. An experiment was designed and conducted using 280 numbered pristine glassine stamp bags. Fingerprints were deposited on some of the clean glassine bags, and the bags were processed with treatment methods selected according to generally accepted methods of processing porous and semiporous surfaces. The chosen methods were magnetic powdering, ninhydrin with chamber, 1,8-diazafluoren-9-one (DFO) with chamber, and a sequential treatment of DFO and ninhydrin, both with chamber. 1-2 Indandione was considered but was ultimately rejected because it requires more time to process and is less commonly used. The selected donors were chosen

\(^2\) 23 bags is the hypergeometric requirement.
to be of varying secretion status and would not be supplying a “groomed” fingerprint. The processed bags were photographed and evaluated using a grading scale. This information will be referred to as Study II. To determine whether the chosen processing methods would affect the weight of the bags, it was determined that the 280 bags would be weighed after fingerprint deposition and again after processing. This will be referred to as Study III. The data collection of the experiment was performed as described in the headings below.

The donors were selected through the use of a voluntary laboratory-wide study at the ACOME. Participation in the voluntary study implied consent to contribute to the donor determination study.

**Method Efficiency Study: Donor Determination**

The donors were selected through the use of a voluntary laboratory-wide study at the ACOME. Participants were asked to deposit a single fingerprint in a block on a sheet of untouched white paper at three separate times of the day: when they arrived at their desks at the start the work day, 20 minutes after washing their hands (without touching any other surfaces), and at the end of the work day. These three conditions were chosen to simulate three very different situations: natural secretions and ambient oils, an essentially blank canvas with only the participant’s own secretions, and hands that may be dried out because of constant washing, glove wearing, or paper handling. The time of deposition was also used to determine what time of the day the full study participants would deposit fingerprints.

The papers were then processed in two batches with petroleum ether-based ninhydrin. The developed prints were graded on a scale from 1 to 3 with 1 as the low end of the development spectrum. The grading was based on ridge quantity and the contrast of development, though the quality was ultimately low. The study resulted in the selection of what were believed to be two relatively good secretors (with scores of 3), two moderate secretors (scores of 2), and one poor secretor (score of 1). The five selected participants would, based on the results of the pilot

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3 Groomed refers to a commonly used fingerprint depositing method of collecting sebaceous secretions from the face (typically the nose or forehead) on the tips of the fingers to ensure that a print of good quality is deposited on the surface.

4 Ninhydrin processing followed the U.S. Department of Justice formula from the Processing Guide for Developing Latent Prints [5].

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study and considerations for donors’ schedules, deposit fingerprints each morning when they first arrived to work.

**Fingerprint Depositing Stage**

Fingerprints were deposited on the glassine bags over four successive days. Each day, each donor gave fingerprints on 10 pristine bags, one for each digit. Additionally, 80 bags without fingerprints were included as a control group. The depositing stage was overseen by a neutral party to minimize bias for the latter part of the study.

**Treatment Stage**

The 280 glassine bags were separated into four equally sized treatment groups, each consisting of 70 bags. Each group was assigned to be treated using one of the following fingerprint development methods: magnetic powder, DFO, ninhydrin, or DFO followed by ninhydrin\(^5\). The 200 bags on which donors had deposited prints were randomly assigned in a balanced fashion, ensuring each treatment group contained exactly one of each digit-donor combination. The 80 untouched bags were assigned into four balanced groups of 20 bags, each of which was treated with one of the four treatments.

The bags were then processed over the course of two days. Both the DFO treatment and the ninhydrin treatment utilized the fingerprint development chamber.

**Photography**

After the bags were processed with the predetermined method, the bags were photographed on a copy stand and adjustments were made (grayscale, color invert) to create a similar visual appearance across all of the images to mitigate possible bias.

**Quality Analysis of Developed Prints**

The collected images were then analyzed by four latent print scientists at the ACOME using a rubric adapted from other literature.

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\(^5\) Processing method specifications for regular black magnetic powder: Sirchie [6]; DFO and ninhydrin formulas were acquired from the Processing Guide for Developing Latent Prints [5].
Rubric Description

The friction ridge development on each of the 280 glassine stamp bags was evaluated using a predetermined grading scale. To ensure that the applied grading system was consistent with current published works, the decision was made to adapt the quality-based grading scale published by Dove [7]. This scale was chosen because the criterion at each grade level is defined in terminology that is widely accepted within the field of fingerprint analysis. It was thought that this would provide each examiner with the most objective scale possible for the aforementioned quality evaluations. One modification was made to the scale as published. The language concerning the suitability for identification was removed. This was done to remove the subjectivity of such evaluations that may fluctuate with the tolerance level of each examiner. Therefore, four examiners with varying levels of training and experience used the rubric found in Table 1 to provide a quality assessment of the friction ridge detail developed on each of the 280 stamp bags.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Usable third-level details (pores, ridge endings, minor ridge deviations) are visible.</td>
</tr>
<tr>
<td>3</td>
<td>No third-level detail, but usable second-level details (bifurcations, ridge endings) are visible.</td>
</tr>
<tr>
<td>2</td>
<td>No usable second- or third-level details, but first-level detail (ridge flow, pattern) is visible.</td>
</tr>
<tr>
<td>1</td>
<td>No usable details at any level, but indications of matrix are present (a smudge).</td>
</tr>
<tr>
<td>0</td>
<td>There is no evidence of a fingerprint having been deposited.</td>
</tr>
</tbody>
</table>

Table 1
The modified rubric used by the four examiners to grade each of the 280 images.

Two additional published rubrics were also considered prior to finalizing the decision to adapt Dove’s scale. These included the Bandy five-point scale [8] and the modified CAST scale [9]. Although the language varies slightly between the two, each of these scales grades the friction ridge quality based on the amount of continuous ridge flow developed. In both cases, the criterion at each grade was defined by surface area development in one-third increments. It was thought that this would allow for a significant amount of subjective interpretation that could be further exaggerated by the varying experience levels of the examiners involved. Therefore, Dove’s scale, with its less subjective criteria, was chosen. This scale was then modified to the above version so that only the criteria that were well defined within the science remained. Examples of fingerprints at the various grades can be found in Figure 1.
Figure 1
Examples of an image from each grading level. All four examiners agreed on the scores. (a) Level 1 (ninhydrin only print); (b) Level 2 (DFO + ninhydrin print); (c) Level 3 (magnetic powder print); (d) Level 4 (ninhydrin only print).
Results

Results of Study I: Qualitative Drug Analysis of Ninhydrin-Processed Stamp Bags

Any breakdown in the heroin samples caused by the humidity chamber during ninhydrin processing was expected to be seen as a decrease in the ratio of heroin to 6-MAM. Figure 2 shows that the percent change in the ratio of heroin to 6-MAM decreased slightly across the majority of the bags after ninhydrin processing with the humidity chamber. This decrease did not affect the qualitative identification of heroin in the samples. Though the fentanyl samples were not expected to break down because of the chemical structure of fentanyl, the three samples were also qualitatively assessed after ninhydrin processing with the humidity chamber. Fentanyl was qualitatively identified in the three samples after processing.

Results of Study II: Evaluation of Latent Print Processing Methods

The relative efficacy of the four fingerprint development treatments (magnetic powder, DFO, ninhydrin, and DFO + ninhydrin) can be examined by comparing the ratings assigned to them by the four examiners.

In most cases, examiners are interested in developing prints of ratings 3 or 4, with 4 being heavily preferred. Ratings of 0, 1, and 2 have relatively little investigative value for forensic casework. With this in mind, the following scoring system was developed for formal analyses.

- A rating of 0, 1, or 2 is worth a score of 0.
- A rating of 3 is worth a score of 0.5.
- A rating of 4 is worth a score of 1.

The scores from the four examiners were averaged to obtain the score assigned to each bag. Figure 3 illustrates the distribution of assigned ratings, separated by the four treatment groups.

Table 2 summarizes the results of this scoring system for the four treatment groups. Under this scoring system, magnetic powder remained the relatively best performing treatment for developing fingerprints. It should be noted that although the finger (1 through 10) used by the donor did not seem to have an effect on the quality of the print, the scores varied from donor to donor. This is illustrated in Figure 4, which shows the scores assigned to each of the five donors.
Table 2

The summarized results of the weighted scoring system.

Donors 1 and 2 turned out to be poor secretors, whereas donors 4 and 5 were good secretors. The data also suggest that the efficacy of each treatment may vary by donor. This is visible in Figure 5, which shows the scores separated by both treatment and donor.

Whereas magnetic powder performed best for donors 1, 2, 4, and 5, it appears that treatments with solely DFO or solely ninhydrin were superior for donor 3.

Results of Study III: Gravimetric Analysis of Empty Stamp Bags

Figure 6 demonstrates the weight before and after the fingerprint development process for each of the bags, with the black diagonal line indicating the no-change line. The blue and red diagonal lines show a change of 0.002 g (the reported uncertainty of measurement) above and below no-change, respectively.

The majority of points lie above or near the no-change line, revealing that most of the bags weighed more after treatment than before. However, we are more interested in the effect separated by different processing treatments, as shown in Figure 7.

Figure 7 reveals that both treatments involving ninhydrin gained noticeably more weight than those involving magnetic powder or DFO alone. A statistical analysis of these changes yields the following average results: magnetic powder, ninhydrin, and the DFO+ninhydrin combination led to statistically significant increases in weight. The observed average increases were 0.0004 g, 0.0017 g, and 0.0013 g, respectively. The DFO treatments resulted in a statistically significant decrease in weight (0.0003 g).
Figure 2

A boxplot showing the percent change in the ratio of heroin to 6-MAM for 23 stamp bags containing known heroin samples after being treated in a humidity chamber.

Figure 3

A bar chart illustrating the number of fingerprinted bags receiving each rating, separated by the four treatment categories.

Figure 4

The black points show distribution of scores assigned to the prints coming from each of the five donors. The red dot indicates the average score for each donor, with the red interval showing a 95 percent confidence interval.
Figure 5

The distribution of scores separated by each donor and each treatment. The black point and interval indicate the average score and corresponding 95 percent confidence interval.

Figure 6

A scatterplot of the weights of the stamp bags both before and after treatment. The black line indicates when the two weights are equal; the red and blue lines represent the upper and lower limits of the uncertainty in measurement (+/- 0.002 g).

Figure 7

A scatterplot of the weights of the stamp bags both before and after treatment, separated into the four treatment groups. The black line indicates when the two weights are equal; the red and blue lines represent the upper and lower limits of the uncertainty in measurement (+/- 0.002 g).
Discussion

Study I: Qualitative Drug Analysis of Ninhydrin-Processed Stamp Bags

Both the heroin and fentanyl samples displayed no changes to texture or composition but were more difficult to manipulate and stuck to the spatula after processing. Although gravimetric analysis for the fentanyl samples was still within the uncertainty of measurement limits, it was noted that the samples displayed significant issues with static. This created an issue with obtaining accurate weights for the samples and could be attributed to the relative humidity within the laboratory during testing.

The extreme humidity of the ninhydrin chamber was expected to cause the breakdown of the heroin samples to 6-MAM. The difference in the ratio of heroin to 6-MAM varied, possibly because of measurement uncertainty, but heroin was certainly not eliminated. Additionally, the sugars in the fentanyl samples were expected to be more moisture sensitive than the other components comprising the sample. Any breach of the glassine bag by either the water or the ninhydrin liquid could have resulted in sample loss via wash out. It is therefore suggested that ninhydrin should be applied with a spray bottle, as it was for the entirety of this study. Tray immersion or brush techniques that may allow the ninhydrin solution to enter through the mouth of the bag are not recommended.

Heroin was not eliminated from the samples exposed to humidity in the ninhydrin chamber. No qualitative ratios were analyzed for the fentanyl samples because fentanyl is not expected to degrade as heroin does. Glassine stamp bags can be processed using ninhydrin without concern that the contents of the bag will be altered beyond evidentiary use.

Study II: Evaluation of Latent Print Processing Methods

Based on the results in Figure 5, magnetic powder yields the highest proportion of high ratings, indicating that this would be the evident choice if only one processing method to develop fingerprints could be used. And while magnetic powder performed best for four of the five donors, it appears that treatments with solely DFO or solely ninhydrin were superior for donor 3. These results suggest that there could be benefits to employing a “mixed strategy”, which would involve applying different development treatments to different bags from the same population to increase the probability of finding an excellent
print. There are, however, factors that might affect the performance of magnetic powder in other conditions that require further investigation.

Fingerprints deposited on a porous surface can be effectively processed within two days of deposition using magnetic powder [10]. However, 99 to 99.5 % of eccrine gland secretion is water [11], which is the first constituent of fingerprint residue to evaporate. Thus, fingerprint development techniques that predominantly adhere to the moisture in a fingerprint, such as magnetic powder, are most useful on recently deposited prints. A portion of the remaining 0.5 to 1.0 percent of eccrine gland secretion consists of amino acids, which are not water soluble. Fingerprint processing techniques that rely on a reaction with amino acids, such as ninhydrin, may be most effective on older print deposits. This time of deposition dependence suggests that a variety of processing techniques could be applied, particularly in cases in which the time since deposition is uncertain.

In this study, the treatments were applied only days after the prints were deposited on the glassine bags. In real casework, it may be months, or even years, after a person has touched a bag that it is processed for fingerprints. Even with a nonporous surface under laboratory controlled conditions, latent fingerprint degradation can cause once identifiable fingerprints to become unidentifiable [12]. If the efficacy of magnetic powder decreases as a function of time, as the study Alcaraz-Fossoul et al. [12] conducted on glass and polystyrene suggests, the results of the processing study are too constrained to accurately depict real world outcomes. No temporal effect was observed, meaning magnetic powder was comparably effective for bags touched on each of the days one through four. For this reason, a timed study in which the glassine bags are processed at longer intervals after fingerprints are deposited is recommended.

Unexpectedly, the friction ridge detail developed with magnetic powder was recovered as a tonal reversal, meaning the furrows of the impressions held powder and the ridges appeared white. The images, therefore, needed to be converted to gray scale and then inverted, which contributed dramatically to the contrast of the final images. Figure 8 (left) shows the same fingerprint before and after (right) the gray scale conversion and inversion were applied. This situation was unavoidable because of the need for uniform images to reduce bias during examination, but likely skewed the scores higher for the powdered prints. The same could be said for the DFO-developed fingerprints. The
images also needed to be inverted and converted to gray scale; however, the comparison of before and after images showed no extraordinary difference in contrast. This perception is most likely due to the fluorescent nature of DFO-developed fingerprints that appear yellow-orange on a black background when examined with an alternate light source.

A second consequence of the images needing to be uniform was the washout of the natural contrast that Ruhemann’s purple creates on a light-colored surface, as shown in Figure 9.

After the scores had been submitted for statistical analysis, the four examiners discussed the shortcomings of the rubric. The consensus was that the rubric left too much room for interpretation. For example, one examiner gave a score of 3 only if the print had identifiable second-level detail with distinct contrast. Another examiner gave a score of 3 if second-level details were observed. During the discussion, it became clear why the identifiable and not identifiable criteria were included in the original rubric; those clauses would have created a more definite delineation between adjacent scores. Additionally, one examiner was using the rubric in a stepwise fashion. For example, a print with no second-level detail apparent but pores visible would not have received a score of 4 but would receive a score of 2 because it did not meet the criteria for a score of 3.

*Study III: Gravimetric Analysis of Empty Stamp Bags*

Overall, the average gains and losses in weight were all within the uncertainty of the measurement (0.002 g) of the ACOME. This means that the weight added to the bags by the selected processing methods is less than the tolerance level for uncertainty.
A fingerprint processed with black magnetic powder exhibiting tonal reversal. Right, the same image after gray scale and inversion application in Photoshop. The grayscale image received a score of 4 from three of the examiners. The fourth examiner gave the grayscale image a score of 3.

Figure 9

(Top image) A ninhydrin-treated fingerprint before and after grayscale application in Photoshop. The grayscale image received a score of 2 from all four examiners.

(Bottom image) A ninhydrin-treated fingerprint before and after grayscale application. The grayscale image received a score of 1 from all four examiners.
Conclusions

Based on the results of this study and the typical age of evidence received in the laboratory, the ACOME will continue processing glassine stamp bags with ninhydrin, but without removing the powder from each bag. The bags will continue to be unfolded, sprayed with ninhydrin, and subjected to heat (~75 °C) with humidity for approximately 4 minutes.

The procedural change has the following significance:

- Fingerprint scientists’ risk of exposure to dangerous substances, particularly fentanyl and its derivatives, will be reduced.
- Fingerprint scientists’ time is saved, resulting in improved efficiency and cost savings. By eliminating the two most time-consuming steps, the time expenditure per bag dropped to approximately 1 minute from 4 minutes with the previous procedure.
- ACOME is able to accelerate its processing and analysis of fingerprints on glassine stamp bags, thus aiding law enforcement.

This experiment was designed to test the effects of common latent print processing methods of semiporous objects on a surface that is being seen more frequently. The authors hope that these suggestions may encourage other laboratories to process glassine stamp bags for fingerprints because this information indicates that glassine bags containing suspected heroin can be processed for latent prints with minimal handling and exposure.

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