Leica Map360: Bloodstain Pattern Analysis

White Paper

Bloodstain Pattern Analysis Workflow

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Abstract

The use of computer aided software to analyse the area of origin of impact patterns is well accepted within the bloodstain pattern community. The use of various computer software, including laser scanners and three-dimensional (3D) drawing technologies, has been the subject of previously authored papers. The purpose of this paper is to explore the integration of 3D point cloud data and bloodstain pattern analysis, specifically area of origin determination, and discuss the developmental validation of the integrated Bloodstain Pattern workflow within Leica Map360. Data capture and analysis was completed utilising the Leica ScanStation P40 and Leica RTC360 laser scanners, Leica Cyclone, and Leica Map360. During the validation, the accuracy and reproducibility of area of origin determinations via the Map360 Bloodstain pattern workflow was evaluated. Various impact patterns were generated in a controlled setting utilising liquid defibrinated sheep blood. Generally, the calculated areas of origin were found to be accurate with respect to the known and similar to results generated with other computer aided area of origin calculations. The maximum absolute errors for the X, Y, and Z[1] axes were 5.4 cm, 17.2 cm, and 10.4 cm, respectively; calculated from a two sided pattern on a flat surface. Evaluating the same pattern with another computer aided area of origin calculation workflow (FORident HemoSpat) resulted in a comparable error of 1.4 cm, 15.2 cm, and 6.9 cm in the X, Y and Z axes, respectively. An additional impact pattern was created which was independently analyzed by fifteen participants, with the maximum absolute errors for the X, Y, and Z axes being 3.0 cm, 3.8 cm, and 2.5 cm, respectively.

Introduction

This paper will discuss the developmental validation of the new Bloodstain Pattern workflow within Map360. The validation evaluated the accuracy of the relative to the known origins (location of liquid blood relative to the target) and evaluated the reproducibility of results.

This validation utilised impact patterns (bloodstain patterns resulting from an object striking liquid blood[2]) which were generated by placing a volume of liquid blood on a striking block and striking the blood with a mallet. During pattern creation, the liquid blood pool is broken into droplets, which land on the target surface and create elliptical spatter stains (bloodstains resulting from an airborne blood drop created when external force is applied to liquid blood[3]). Stains in an impact pattern vary in shape from circular to elliptical; however, stains having an elliptical shape and upward directionality (indicated by the stain's directional tail) can be utilised to determine the area of origin (the space in three dimensions to which the trajectories of spatter can be utilised to determine the location of the spatter producing event[4]). This analysis involves measuring the width and length of individual bloodstains to determine the stain's angle of impact (the angle [alpha], relative to the plane of a target, at which a blood drop strikes the target[5]). This calculation is done via the Balthazard equation[6] described below:

Angle of Impact = Arc Sin (stain width/stain length)

To complete the analysis, physical strings may be attached to a target surface to represent the straight line flight path of an individual blood droplet, culminating in the impact on the target at the calculated angle.

The Map360 bloodstain pattern workflow automates measurements and calculations. The user (a qualified bloodstain pattern analyst) defines the size of the bloodstain and the software measures the stain,

1 For the purposes of this validation and this paper, the X axis measures the horizontal distance, the Y axis measures the vertical distance and the Z axis measures the distance out from the target

2 Terms and Definitions in Bloodstain Pattern Analysis. 1st ed.

3 Terms and Definitions in Bloodstain Pattern Analysis. 1st ed.

4 Terms and Definitions in Bloodstain Pattern Analysis. 1st ed.

5 Terms and Definitions in Bloodstain Pattern Analysis. 1st ed.

6 Bevel, T.; Gardner, R. M. Bloodstain Pattern Analysis: with an Introduction to Crime Scene Reconstruction, Bevel and Gardner, p 191

calculates the angle of impact for each individual stain, and maps its trajectory in 3D space. The program utilises an algorithm to compute the area of origin. A series of linear equations are solved via an efficient matrix approach which determines the nearest point in 3D space to all selected 3D vectors simultaneously, thereby calculating the area of origin in the X, Y, and Z directions. Each vector is derived from the ellipse size and directionality, which is set by the user during analysis. The area of origin calculation considers all the selected trajectory lines; it is the responsibility of the analyst to identify outliers and exclude them from analysis.

The Map360 BPA workflow, essentially a virtual stringing technique, replaces the need for on-scene physical stringing, while still providing a visual representation of the individual droplet trajectories. The workflow reduces time on scene and analysis time by eliminating the need to take tedious hand measurements. The workflow also has the benefit of reducing human error associated not only with hand measurements and calculations, but also with placement of physical strings. Additionally, because the workflow is completed within a digital data set, it is nondestructive and infinitely repeatable, should there be a need for reanalysis. Results may be observed in 3D and are reported in easy to understand deliverables.

The participants in this study were experienced crime scene investigators and forensic scientists with varying degrees of expertise in bloodstain pattern analysis; however, all participants previously completed a 40-hour basic bloodstain pattern analysis course. Participants were novice users of the bloodstain workflow and were therefore provided with step by step directions to complete the workflow; however, each user was responsible for selecting stains within the pattern.

Method

This study consisted of two portions; accuracy evaluation (completed in two phases) and reproducibility evaluation.

Accuracy Evaluation

The first portion of the validation involved creating various impact patterns and analysing the patterns utilising the Map360 bloodstain workflow and the FORident HemoSpat software and comparing the results of each software to the known origin. The author of this paper was the primary analyst during the accuracy evaluation portion of the validation and as such, was not involved in pattern creation.

Pattern Creation

Five patterns were generated during the accuracy evaluation portion of the validation. To maintain the integrity of the validation, a blind experiment format was utilised wherein the primary analyst did not witness pattern creation or have knowledge of the known origin in order to reduce potential experimental biases. Five patterns were created as defined below in order to evaluate the efficacy of the workflow when analysing the various types of patterns which could be encountered in case work.

- Two sided pattern on a flat wall
- One sided pattern on a flat wall
- Two sided pattern on two perpendicular walls
- Two sided pattern on two perpendicular walls and an intermediate object
- Two sided pattern on two perpendicular walls and a slanted ceiling

Two sided patterns are those which contain stains that radiate out from the area of origin on both the left and right sides of the patterns. One sided patterns contain stains on only one side of the area of origin and are therefore lacking in stains on either the left or right side. One sided patterns and patterns on flat walls provide less data to analysts than well-formed two-sided patterns on multiple surfaces and were therefore included in the validation to ensure the workflow is robust enough to handle the variety of pattern types an analyst will encounter.

All targets were constructed using wooden frames and white cardboard sheets. A striking surface was positioned by the pattern creation team at varying heights and locations for each pattern. These variations mimic the conditions encountered in casework. The location of the striking surface was measured by a member of the pattern creation team via handheld laser distance meter and recorded as the “known origin” for each pattern. The areas referred to as the known origin were utilised for determining error from the true known; however, these measurements were taken from the approximate center of each striking surface and do not account for the random dispersal of blood during pattern creation. Blood is dispersed from several points during impact pattern creation and the liquid source of blood formed a small pool on the striking surface several centimetres in diameter and therefore cannot be accurately quantified as a single point. Approximately 2 millilitres of defibrinated sheep’s blood was placed on the striking surface and struck with a smooth face plastic head mallet by a member of the pattern creation team.

Data Collection

The impact patterns were documented photographically and via 3D laser scanning. The Scan Station P40 and the RTC360 laser scanners were utilised to collect point cloud data for each target. Scans captured with the RTC360 were captured at a resolution of 3mm at 10 metres, with a scanner to target distance of approximately 1 metre. Immediately after pattern creation, a member of the pattern creation team scanned the scene with the striking surface in place. The striking surface was removed from the pattern area and the floors were covered with clean butcher paper to prohibit the author from examining the floor. The author began examination and documentation of each pattern by first placing black and white adhesive targets within the pattern area. These adhesive targets are utilised during the bloodstain workflow to align photographs to the cloud data, thus enabling the analyst to view high resolution images of individual stains. All photographs were captured using a Nikon D810 digital SLR camera using appropriate photographic techniques (refer to figure 1). With the adhesive targets in place, the pattern area was rescanned (refer to figure 2).

Figure 1: Photographs of the bloodstains were captured with black and white targets for image alignment.

Figure 2: The setup was scanned using the Leica ScanStation P40 and Leica RTC360.

The captured point cloud data was registered together with Leica Cyclone, and the floors and striking surfaces were removed by a member of the pattern creation team to prohibit examination by the author. The registered and edited data was utilised for all subsequent analysis.

Data Analysis

Data was analysed via two methods during the accuracy phase of the validation; the Map360 bloodstain pattern workflow and FORident Hemospat. Each pattern was analysed twice with the Map360 workflow, once using appropriate stains selected by the author (during phase one) and once using a defined set of stains selected by the author for examination within both FORident Hemospat and Map360 (during phase two). With the exception of stain selection, the workflow methodology within Map360 was the same for each analysis.

The bloodstain workflow utilises an intuitive ribbon (refer to figure 3) to guide analysts through six analytical steps.

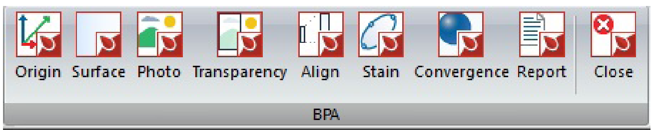

Figure 3: The intuitive BPA Ribbon in Map360 walks you through each step in the workflow.

1. Defining the coordinate system and room origin

   The first step in the BPA workflow is to define the coordinate system and origin for the drawing. The coordinate system is used to provide the XYZ results for the area of origin and stain positions. The software allows users to select from several coordinate system options and define the origin from which they want all measurements referenced. The origin can easily be placed at the intersection of walls and floors within the data set; however, the user may elect to place the origin wherever is most appropriate within the given data set.

2. Identifying surfaces from point cloud data or measured points

   A surface is needed to accurately place the images within the data set and accurately draw the stains and straight line trajectories for analysis. This surface is user defined and can be a wall or object within the scene that bears bloodstains. All surfaces are considered a flat plane within the data set. Complex or irregular objects may necessitate the use of several surfaces.

3. Align and scale images directly to the surface

   In order to enable the analyst to view and select the margins of stains from a high resolution image, the workflow inserts photographs into the dataset and places them on the user defined surfaces. This is done by picking corresponding points within the images and the scan data (for example, the aforementioned black and white adhesive targets). To ensure proper alignment and scaling of images, users should select points that span the image and may select 2 or more points for each image.

4. Analyse stains to include in the convergence analysis

   Once the images are appropriately scaled and aligned to the data set, the analyst will conduct stain selection from the image, as in traditional casework. The analyst may zoom in on the image and, following the on screen prompts from the software, select the leading and back end of each stain. The software then places a visual ellipse on the selected stain, and the analyst may adjust the size of the ellipse to suit the width of the selected stain. Once the stain is selected, the length, width, and rotation of the ellipse can be adjusted by the analyst as needed. This step is repeated as many times as needed to select an appropriate number of stains for analysis. There is no upper or lower limit on the number of stains which may be utilised.

5. Visualise the area of origin in 3D with a sphere or point

   Once the analyst has completed stain selection and analysis on each selected surface within the pattern area, the trajectory lines will converge in 3D space. The analyst can view the trajectories in real time as they are added. To calculate the area of convergence, the trajectories are added to a convergence group by the analyst, who also selects a reference origin (previously defined in step one of the workflow). The user may choose to exclude stains from analysis at this juncture and may choose to display the area of origin within the point cloud utilising either a 3D sphere (of user defined size) or a point.

6. Create a BPA report with the calculated results

   The final step in the Map360 BPA workflow is to create a report with the calculated results. This report includes a screenshot of the drawing area displaying the area of origin as well as the calculated results including standard deviations and a list of each stain utilised in analysis (refer to figure 4)

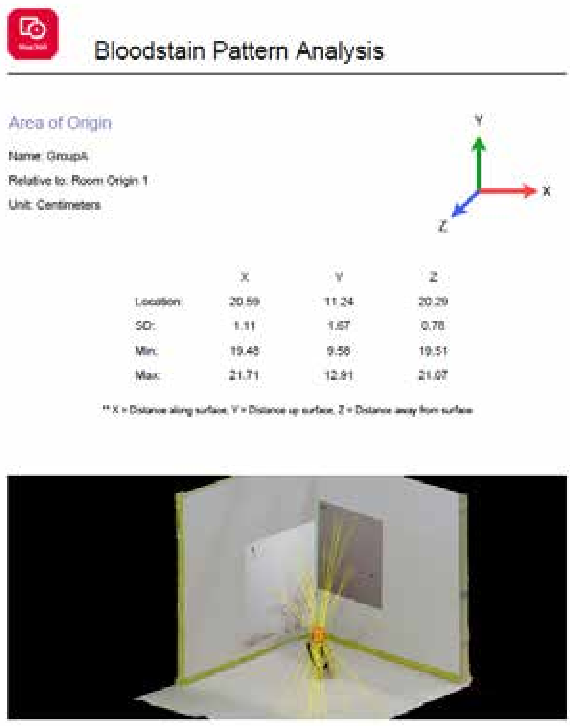

Figure 4: The front page of the BPA report showing the calculated Area of Origin results.

Results

During the first phase of the validation, the author selected stains from each pattern which were appropriate for area of origin determination without any further guidelines. Approximately forty stains were utilised in each pattern. In all data sets, the coordinate system was set such that the X direction represented the horizontal location (left to right), the Y direction represented the vertical direction (up from floor) and the Z direction represented the distance out (in front of) from the wall. The results for this phase of the validation are contained within table 1.

Table One: Phase One Results			
Pattern Description	**Known Area of Origin (Reference Point)**	**Calculated Area of Origin**	**Absolute Error**
Two sided pattern on a flat wall	(89.7, 30.0, 46.1)	(95.1, 44.5, 35.7)	(5.4, 14.5, 10.4)
One sided pattern on a flat wall	(111.0, 57.6, 41.6)	(108.8, 66.8, 37.2)	(2.2, 9.2, 4.4)
Two sided pattern on two perpendicular walls	(56.5, 58.7, 11.7)	(52.7, 58.8, 9.4)	(3.8, 0.1, 2.3)
Two sided pattern on two perpendicular walls and an intermediate object	(66.2, 35.9, 59.6)	(66.1, 37.5, 58.2)	(0.1, 1.6, 1.4)
Two sided pattern on two perpendicular walls and a slanted ceiling	(57.5, 61.6, 66.8)	(54.8, 64.6, 63.7)	(2.7, 3.0, 3.1)
*all data reported in centimetres			

During the second phase of the validation, the author selected approximately twenty stains per pattern to analyse with both the Map360 bloodstain pattern workflow and FORident HemoSpat to compare the methodologies. The results for this phase of the validation are contained within table 2.

Table Two: Phase Two Results					
Pattern Description	**Known Area of Origin (Reference Point)**	**Calculated Area of Origin Map 360 Workflow**	**Absolute Error**	**Calculated Area of Origin Hemospat**	**Absolute Error**
Two sided pattern on a flat wall	(89.7, 30.0, 46.1)	(92.7, 47.2, 39.6)	(3.0, 17.2, 6.5)	(91.1, 45.2, 39.2)	(1.4, 15.2, 6.9)
One sided pattern on a flat wall	(111.0, 57.6, 41.6)	(111.5, 59.1, 39.3)	(0.5, 1.5, 1.7)	(115.4, 58.9, 42.3)	(4.4, 1.3, 0.7)
Two sided pattern on two perpendicular walls	(56.5, 58.7, 11.7)	(53.3, 56.7, 9.8)	(3.2, 2.0, 1.9)	(55.0, 56.7, 11.5)	(1.5, 2.0, 0.2)
Two sided pattern on two perpendicular walls and an intermediate object	(66.2, 35.9, 59.6)	(63.4, 40.2, 57.9)	(2.8, 4.3, 1.7)	(65.3, 38.4, 61.6)	(0.9, 2.5, 2.0)
Two sided pattern on two perpendicular walls and a slanted ceiling	(57.5, 61.6, 66.8)	(56.1, 61.9, 61.6)	(1.4, 0.3, 5.2)	(59.0, 56.7, 65.9)	(1.5, 4.9, 0.9)
*all data reported in centimetres					

Importantly, the same patterns were utilised during the first and second phases of the validation, resulting in the reanalysis of patterns. A comparison of the results can be found in table 3.

Table Three: Comparison of Phase One and Phase Two Results					
Pattern Description	**Known Area of Origin (Reference Point)**	**First Calculated Area of Origin Map 360 Workflow**	**Absolute Error**	**Second Calculated Area of Origin Map 360 Workflow**	**Absolute Error**
Two sided pattern on a flat wall	(89.7, 30.0, 46.1)	(95.1, 44.5, 35.7)	(5.4, 14.5, 10.4)	(92.7, 47.2, 39.6)	(3.0, 17.2, 6.5)
One sided pattern on a flat wall	(111.0, 57.6, 41.6)	(108.8, 66.8, 37.2)	(2.2, 9.2, 4.4)	(111.5, 59.1, 39.3)	(0.5, 1.5, 1.7)
Two sided pattern on two perpendicular walls	(56.5, 58.7, 11.7)	(52.7, 58.8, 9.4)	(3.8, 0.1, 2.3)	(53.3, 56.7, 9.8)	(3.2, 2.0, 1.9)
Two sided pattern on two perpendicular walls and an intermediate object	(66.2, 35.9, 59.6)	(66.1, 37.5, 58.2)	(0.1, 1.6, 1.4)	(63.4, 40.2, 57.9)	(2.8, 4.3, 1.7)
Two sided pattern on two perpendicular walls and a slanted ceiling	(57.5, 61.6, 66.8)	(54.8, 64.6, 63.7)	(2.7, 3.0, 3.1)	(56.1, 61.9, 61.6)	(1.4, 0.3, 5.2)
*all data reported in centimetres					

Reproducibility Evaluation

The second portion of the validation involved creating an additional impact pattern which was analysed by various analysts utilising the Map360 bloodstain workflow. The author of this paper was involved in the pattern creation during this stage of the validation.

Pattern Creation

One pattern was generated during the reproducibility evaluation portion of the validation. This pattern was a two sided pattern located on two perpendicular walls. As in the first portion of the validation, the target utilised was constructed using a wooden frame and white cardboard sheeting.

A striking surface was positioned in the corner of the target area (refer to figure 5) and approximately 2 millilitres of defibrinated sheep's blood was placed on the striking surface. As in the first portion of the validation, a handheld laser distance meter was utilised to measure the location of the blood source. The liquid blood was struck once with the smooth face of a plastic head mallet by a member of the pattern creation team.

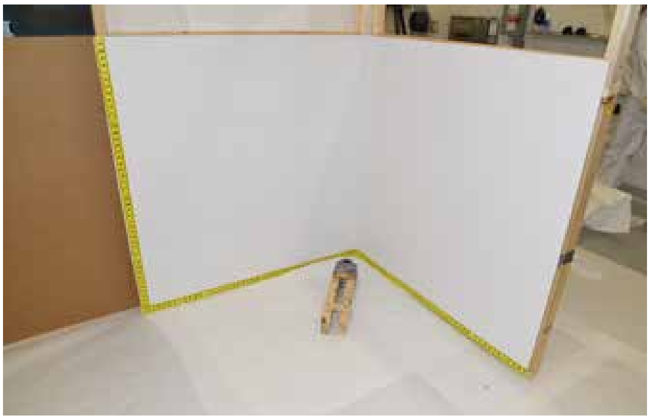

Figure 5: The setup with the striking surface that created the two sided pattern on two perpendicular walls for the reproducibility evaluation.

Data Collection

The generated impact pattern was documented photographically and via 3D laser scanning. The author examined and documented the target using the same methodology utilised in the first portion of the validation. The RTC360 laser scanner was utilised to collect point cloud data at a resolution of 3mm at 10 metres, with a scanner to target distance of approximately 1 to 2 metres. The target was scanned with the striking surface in place.

The striking surface and floor were removed from the point cloud data by the author. The edited data set was published and delivered to external analysts along with photographs of the pattern for analysis. The striking surface and floor were not removed from the point cloud data utilised by analysts within the author's agency.

Data Analysis

Data was analysed utilising the Map360 bloodstain pattern workflow by fifteen analysts (including the author). Analysts selected stains within the pattern at their own discretion and were instructed to utilise the bloodstain workflow as detailed above.

Results

Participants in the reproducibility evaluation portion of the validation were instructed to select a coordinate system such that the X direction represented the horizontal location (left to right), the Y direction represented the vertical direction (up from floor) and the Z direction represented the distance out from (in front of) the wall. The results for this phase of the validation are contained within table 4.

Table Four: Repeatability Evaluation Results		
Known Area of Origin (Reference Point) (19.1, 11.5, 19.5)		
Analyst	**Calculated Area of Origin**	**Absolute Error**
Author**	(20.6, 11.2, 20.3)	(1.5, 0.2, 0.8)
Internal Analyst 1*	(19.6, 12.0, 20.8)	(0.5, 0.5, 1.3)
Internal Analyst 2*	(20.5, 11.2, 19.8)	(1.4, 0.3, 0.3)
Internal Analyst 3**	(21.4, 9.0, 19.9)	(2.3, 2.5, 0.4)
Internal Analyst 4*	(20.3, 8.2, 19.1)	(1.2, 3.3, 0.4)
Internal Analyst 5*	(19.7, 10.2, 20.9)	(0.6, 1.3, 1.4)
Internal Analyst 6*	(21.2, 8.9, 20.7)	(2.1, 2.6, 1.2)
Internal Analyst 7*	(19.7, 8.6, 17.9)	(0.6, 2.9, 1.6)
Internal Analyst 8**	(19.6, 7.7, 19.3)	(0.5, 3.8, 0.2)
Internal Analyst 9**	(20.1, 12.3, 20.7)	(1.0, 0.8, 1.2)
External Analyst 1**	(19.0, 9.3, 17.6)	(0.1, 2.2, 1.9)
External Analyst 2**	(17.5, 11.4, 17.0)	(1.6, 0.1, 2.5)
External Analyst 3**	(22.1, 11.2, 19.4)	(3.0, 0.3, 0.1)
External Analyst 4*	(20.0, 10.1, 19.3)	(0.9, 1.4, 0.2)
External Analyst 5**	(20.3, 11.8, 18.8)	(1.2, 0.3, 0.7)
*denotes completion of basic training in bloodstain pattern analysis **denotes completion of advanced training in bloodstain pattern analysis All data reported in centimetres		

The calculated areas of origins were generally accurate with respect to the known area of origin and in concordance with each other. The range of calculated results is reflected within table 5.

Table Five: Range of Calculated Results		
	Highest Calculated Value	**Lowest Calculated Value**
X (horizontal)	22.1 cm	17.5 cm
Y (vertical)	12.3 cm	7.7 cm
Z (out from wall)	20.9 cm	17.0 cm
*all data reported in centimetres		

The report generated by the Map360 software also includes the computer calculated standard deviation, a measure of the dispersion of a data set, in the X, Y and Z axes. The standard deviations for each analyst can be found in table 6.

Table Six: Repeatability Evaluation Standard Deviation Results	
Analyst	**Calculated Standard Deviation**
Author**	(1.11, 1.67, 0.78)
Internal Analyst 1*	(1.04, 1.21, 0.46)
Internal Analyst 2*	(1.52, 1.24, 0.66)
Internal Analyst 3**	(1.49, 1.55, 0.74)
Internal Analyst 4*	(1.43, 1.35, 0.56)
Internal Analyst 5*	(1.32, 1.47, 1.03)
Internal Analyst 6*	(1.45, 1.38, 1.10)
Internal Analyst 7*	(1.80, 1.13, 0.45)
Internal Analyst 8**	(1.72, 1.72, 0.90)
Internal Analyst 9**	(1.34, 1.15, 1.22)
External Analyst 1**	(1.72, 1.56, 1.08
External Analyst 2**	(2.05, 2.06, 0.59)
External Analyst 3**	(1.19, 1.06, 0.93)
External Analyst 4*	(1.36, 1.02, 0.62)
External Analyst 5**	(2.20, 1.37, 0.74)
*denotes completion of basic training in bloodstain pattern analysis **denotes completion of advanced training in bloodstain pattern analysis All data reported in centimetres	

Discussion

For the purposes of quantifying the error rate in this study, a singular point (the reference point) was selected within the known area of origin (liquid blood source) to be the metric against which calculated results were evaluated. This reference point is considered the known area of origin, however, it should be noted when considering error that the true area of origin is not a single point and cannot be precisely evaluated as such.

There is not an industry accepted error rate when considering area of origin calculations. The aim of bloodstain pattern analysis is not to determine a specific point location from which blood originated, but to determine a general location[7]. Most analysts utilise a general size descriptor in lieu of a precise quantitative measurement. Bevel and Gardner offer 30.5 cm[8] as an appropriate range for acceptable results, and later amended this range to be "somewhere between the size of a tennis ball up to a soccer ball."[9] Considering this, the calculated error is therefore well within the industry standard. Further, the error and calculated areas of origin when comparing Map360 and HemoSpat during the first portion of the validation were found to be generally similar.

During the first portion of the validation, the author analysed the patterns twice utilising the Map360 workflow. Variations in the results were observed (refer to table 3) between the first and second iterations. There are several reasons for these variations, the most significant of which is stain selection. Different stains were utilised during each analysis, which would account for variations in the calculated area of origin. Additionally, the author gained more experience with the workflow during the process and was therefore a more experienced user during the second analysis. The difference in calculated results between iterations ranged from 0.4cm to 7.7 cm and the average difference was 2.4 cm.

Generally, the results are in accordance with expectations. The highest errors were observed in calculations regarding the vertical direction. Regardless of the technique utilised, analysts are unable to exactly reconstruct the true flight paths of each individual droplet in an impact pattern. It is generally accepted that the calculated height represents the upper limit of the true height origin of the known source of blood due to the use of a straight line assumption[10] employed during calculations. Due to the effects of gravity and air resistance, the true flight path of a blood droplet in flight is parabolic; however, traditional calculations and the Map360 BPA workflow represent this flight path as a straight line. As Alfred Carter notes, "it is reasonable to assume that the point of convergence is located somewhere above the source and therefore can be used as an upper limit for the height of the source."[11]

Interestingly, most of the analysts (80% of participants) during the reproducibility phase of analysis calculated a point lower than the known height of the blood source. There are several possible reasons for this calculation. Firstly, the users who participated in the reproducibility portion of the validation were (with the exception of the author) using the bloodstain workflow for the first time and therefore inexperienced users of the software. Second, more than half of the analysts who generated calculations in the vertical direction lower than the known height of the blood source were novice bloodstain pattern analysts who had not completed advanced bloodstain training and were not actively performing casework in bloodstain pattern analysis. Third, it is possible the analysts set the user defined gamma angle (the directional angle between the long axis of a spatter stain and a defined reference line on the target[12]) for selected stains in a manner such that the trajectories for individual stains indicated a lower than accurate origin point. Fourth, it is probable that the inclusion of outliers by some analysts in their respective data sets had some impact on the lower than expected height calculations. Fifth, it is possible the image alignment was done such that the images were aligned slightly lower within the scan data than their true height or the user defined origin was placed slightly above the true floor. Regardless of the reasons for the deviation, analysts should understand that height calculations generated by software may not represent the upper limit of the possible true height unlike hand calculated results.

The standard deviations calculated and included in the bloodstain pattern analysis report are a reflection of the range of values within the dataset. The calculated values with respect to standard deviations calculated in the reproducibility portion of this validation were

7 Kish, P. Advanced Bloodstain Pattern Analysis Course Laboratory Manual, p12

8 Bevel, T.; Gardner, R. M. Bloodstain Pattern Analysis: With an Introduction to Crime Scene Reconstruction, 2nd ed.; p 190

9 Bevel, T.; Gardner, R. M. Bloodstain Pattern Analysis: With an Introduction to Crime Scene Reconstruction, 3rd ed.; p 191.

10 James, S., Kish, P., Sutton, T.P Principles of Bloodstain Pattern Analysis: Theory and Practice; p 243-244

11 James, S. Scientific and Legal Applications of Bloodstain Pattern Interpretation, p 18

12 Terms and Definitions in Bloodstain Pattern Analysis. 1st ed

generally very low. The analyst should use caution when interpreting the data presented in the bloodstain report and understand that standard deviation is a measure of precision, not accuracy. Precision assesses how close measured values are to each other, while accuracy reflects how close a measured value is to the true value (refer to figure 6).

It is critical users understand that the Map360 bloodstain pattern workflow is not a substitute for training and should only be utilised by qualified and competent bloodstain pattern analysts.

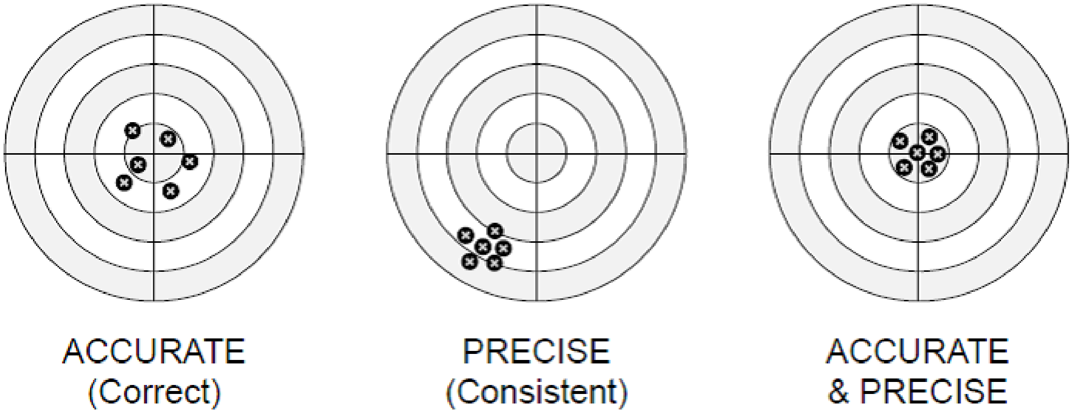

Figure 6: A visual comparison of accuracy vs precision.

The generated report includes the "min" and "max" value for the X, Y, and Z axes. Analysts should be aware this figure represents one standard deviation above ("max") and below ("min") the calculated area of origin. This author's agency utilises two standard deviations from the calculated area of agency when reporting results. Each agency should develop its own internal standards for how to utilise this data and how to present the results.

Analysts select points in the data set by viewing and selecting points on the aligned images. It is critical the scan data as well as the photographs be acceptable and appropriate for analysis. Analysts should utilise the highest resolution scans and also minimise the scanner to target distance whenever possible. Additionally, if printed targets are utilised to assist in alignment and scaling photographs, a laser printer should be utilised in lieu of an inkjet printer, as targets printed with a laser printer return better to the scanner. Photographs should be taken using standard forensic photography techniques for capturing examination quality photographs. The best photographs for analysis are those which do not overlap, have acceptable resolution for individual stains, and which contain alignment points that span the entirety of the image.

Conclusion

The bloodstain pattern workflow within Leica Map360 is a reliable methodology for area of origin calculations. It is a useful and reasonable alternative to traditional hand calculations used by bloodstain pattern analysts and offers advantages over existing software utilised in bloodstain pattern analysis in that it provides the added benefit of visualising the area of origin within a three dimensional rendering of the crime scene. The analyst is able to easily view results from different angles.

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