## B28 Uncertainty in the Estimated Angles of Impact of Freely Falling Blood Drops

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After attending this presentation, attendees will learn how to determine the confidence limits for the calculated angle of impact of a falling blood drop with a target surface. This preseantation will outline the relevant experimental data for a particular target surface and the statistical treatment of this data.

This presentation will impact the forensic community and/or humanity by demonstrating that the uncertainties in the calculated angles of impact of blood drops with target surfaces are considerably smaller than standard texts on bloodstain pattern analysis claim.

The goal of this presentation is to provide crime reconstructionists with a validation of the Balthazard formula for the calculation of the angle of impact of a blood drop with a target surface. This presentation also will also provide estimates for the uncertainty in a calculated angle of impact for ranges of impact ranging from 10 to 90 degrees.

Crime scene reconstructionists and bloodstain pattern analysts frequently use the Balthazard formula for calculating the angle of impact of a freely falling blood drop with a target surface from the dimensions of the resulting blood spot. Blood drops impacting a flat surface at an angle $\theta$ produce an elongated blood spot having length **L** and width **W.** The angle $\theta$ is then given by the equation:

$$\theta = \arcsin (W/L)$$

In 1993 the U.S. Supreme Court set out a number of criteria for the admission of scientific evidence; among them is the known or potential error of a scientific technique. Books on bloodstain pattern analysis rarely discuss the uncertainties in the calculated angle of impact. Bevel and Gardner's widely used text *Bloodstain Pattern Analysis* suggests that the calculated angles are accurate to within five to seven degrees.

This research was undertaken to determine the 95 and 99% confidence limits for the estimated angles of impact of blood drops. Fifteen microliter drops of human blood were allowed to fall ten and thirty-six inches onto the uncoated surface of white poster board with impact angles of approximately 10, 20, 30, 40, 50, 60, 70, 80 and 90 degrees. Fifteen drops of blood were dropped at each angle of impact and each distance of fall. Fifteen microliters was found to be the smallest volume of blood that would fall freely from the disposable tip of a Pipetman pipetter. Two different distances of fall were used to determine if the estimated angles of impact showed any dependence on the distance of fall. Theoretically there should be no such dependence. The untreated surface of the white poster board was chosen as the target surface to reduce the flow of the blood drops after impact. The target surface was held in a homemade device made from Plexiglas and wooden dowel rods. Slots were cut in the Plexiglas at angles ranging from 10 degrees to 90 degrees; the angles of the slots were measured after they were cut. The lengths and widths of the blood spots were measured with a Cen-Tech 4 inch digital caliper. Three of the blood spots produced at an angle of impact of 80 degrees and a thirty-six inch distance of fall were discarded because their widths were greater than their lengths. The measured lengths and widths of the blood spots were used to calculate the angle of impact using the Balthazard formula. The means and standard deviations of the calculated angles of impact were determined for each angle of impact and each distance of fall.

Analysis of variance (ANOVA) was performed on the calculated angles of impact. For a ten inch distance of fall an F value of 1187 was obtained, while for a thirty-six inch distance of fall an F value of 1288 was obtained. These results show that the Balthazard formula is statistically significant at the 99.5% level. More importantly, because these two F values exceed the critical F values for the 99.5% confidence level by more than a factor of four, the Balthazard formula is shown to be a satisfactory predictive tool.

The standard deviation of the calculated angle of impact was found to increase with the angle of impact, in agreement with previously published work. The confidence range (the difference between the upper and lower confidence limits) for the calculated angles of impact were determined at the 99% confidence level using:

$$2t_{0.005, n-1} \frac{s}{\sqrt{n}}$$

where **t** is Student's t, **s** is the standard deviation and **n** is the number of data points used to calculate **s**. The table below shows the confidence ranges for the angles of impact from 10 to 90 degrees for both distances of fall.

| Approximate Angle of Impact | Distance of Fall = 10 Inches | Distance of Fall = 36 Inches |
|---|---|---|
| 90 | 6.410283 | 8.255688 |
| 80 | 11.2365 | 7.701132 |
| 70 | 3.365768 | 4.722746 |
| 60 | 2.463193 | 2.667552 |
| 50 | 2.148248 | 1.754003 |
| 40 | 1.686314 | 2.435882 |
| 30 | 1.136359 | 1.993076 |
| 20 | 0.795556 | 1.59836 |
| 10 | 1.46632 | 0.710401 |

Up to an angle of impact of 60 degrees the uncertainty in the calculated angle of impact is less than 3 degrees, substantially better than the uncertainty claimed by Bevel and Gardner.

**Bloodstain Pattern Analysis, Crime Scene Reconstruction, Criminalistics**