Draft Abstract

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

Jon A. McGuire, MFS, and Walter F. Rowe, Ph.D., Department of Forensic Sciences, The George Washington University, Washington, DC

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 θ produce an elongated blood spot having length L and width W. The angle θ is then given by the equation

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

Books on bloodstain pattern analysis rarely discuss the uncertainties in the calculated angle of impact. Bevel and Gardner suggest 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. 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 their impacts. The target surface was held in a homemade device fabricated from Plexiglas and wooden dowel rods. Slots were cut in the Plexiglas at various angles 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 pieces of data 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.