ON MEASURING THE VOLUME OF VERY SMALL DROPS OF FLUID BLOOD AND CORRELATION OF THIS RELATIONSHIP TO BLOODSTAIN DIAMETER

Herbert Leon MacDonell* and Kiyomi De Lige**

I) INTRODUCTION:

From time to time a question on bloodstains that attorneys seem to feel is important enough to ask is, "What was the volume of blood required to have produced that bloodstain?" If the stain in question resulted from a medium or high velocity impact, or if it had been produced by expiration of blood from either the nose or mouth, or if it was a portion of a cast-off pattern, the size of the stain would be very small as we all know. How small is very small?

Some critics have objected to what the senior author and Lorraine Fiske Bialousz defined as a "normal" blood drop in their original bloodstain research for the Law Enforcement Assistance Administration, Department of Justice (1). That term, along with several others, was a part of their "working vocabulary" at the time and simply described a drop having a volume of 0.050 ml (or 50 microliters, or 50 lambda). Although this volume is the normal volume that all analytical chemists learn drops from a pipette, burette or a medicine dropper, it is true that a knife tip, ice pick, or other pointed instrument can let a blood drop of a smaller volume fall free because of the very low surface area of these types of instruments. Experiments conducted with common surfaces found at crime scenes, fingers, arms, table edges, bed clothing, etc., all produce the "normal" drop, however. The expression "normal" was adopted so when an investigator saw a bloodstain that was much smaller than the stain produced by this "normal" drop, he knew that some "abnormal" condition prevailed. Usually, this smaller bloodstain resulted from energy, or activity as described in the first paragraph. Nevertheless, our critic should be aware that over fifteen years ago we changed our terminology of the "normal" drop to the "typical" drop. Now there should be harmony in the ranks even though a "typical" drop is normally the same as a "normal" drop, which is typically the same as a "typical" drop, which is.....ad infinitum. Besides, contrary to his claim, this critic was not <u>taught</u> that it was impossible to have smaller drops dripping from the point of a sharp instrument. Quite to

*Director, Laboratory of Forensic Science, Corning, NY 14830
**Research Associate, Laboratory of Forensic Science

the contrary, he was apprised of the above information but either didn't listen at the time so he did not learn what was being presented, or possibly he simply likes to make big rainstorms out of very little drops, (or driplets)? Or could it be mountains out of mole hills? Really, who cares? We all have umbrellas!

In any event, and with consideration of the possible consequences as reported in detail above, let us propose the term "very small bloodstain" to describe very small bloodstains. The diameter, or if an ellipse, the width, of these bloodstains is arbitrarily taken as a maximum of two millimeters (2 mm). Should others wish to take either larger, or smaller, diameters and still call their bloodstains "very small bloodstains" we herein grant license for them to do so. The MacDonell/De Lige "very small bloodstain" has a maximum diameter of two millimeters (2mm).

II) OBJECTIVES:

This study was divided into four specific objectives:

First, a means of producing a variety of very small bloodstains had to be developed.

Second, blood drops on a surface had to be quickly removed so their volumes could be measured. This procedure had to be performed rapidly to prevent any significant loss of liquid volume from evaporation or, if a porous surface, to prevent excessive soaking into the medium.

Third, the correlation of blood volume to the width and/or area of the bloodstain had to be determined in a manner that the results could be applied to unknown bloodstains at a crime scene.

Fourth, small, known volumes of blood had to be deposited onto various surfaces and a mechanism had to be implemented for the removal of this blood. A method for accurate measurement of the removed blood volumes also had to be incorporated so the effectiveness of the removal mechanism could be evaluated.

III METHODOLOGY:

In an effort to achieve our objectives, we did the following:

1) Production of very small bloodstains: Freshly drawn human blood, well mixed with an anti-coagulant in a vacutainer (R) tube, was allowed to soak up into the bristles of a small, coarse brush. Blood was then projected from the brush by simply compressing the bristles laterally and then releasing them so that they snapped back to their normal, more erect, position. The brush was positioned so that blood which was

projected from it struck some suitable target such as glass, Formica (R), plastic, cardboard or other flat material. We also found that a toothbrush or test tube brush worked quite well. In fact, almost any kind of small brush will yield acceptable results. Also, simply "flicking" blood from the fingertips is an excellent way to produce somewhat larger bloodstains. A mastery of this amazing technique does not require much practice before excellent results may be easily obtained and the investigator feels great confidence.

Several angles of impact were achieved by tilting the target in front of the projection method of choice. We were not attempting to achieve any specific angles, rather, simply produced a random variety of angles of impact which were measured using the width/length arc sin method. The angles of impact are recorded in the tables that follow.

2) Measurement of Blood Drop Volume: Undoubtedly, there are many techniques that could be employed to measure the volume of small deposits of a liquid on a surface. We adopted one that is relatively simple, accurate, and may be duplicated in almost any laboratory. This method is simply to touch the surface of the liquid with a capillary tube which allows the fluid to flow up into the tube. To remove liquid blood from the surface as completely as possible, it is necessary to tilt the surface to nearly vertical. In this somewhat ninety degree configuration, it is possible to reduce the effect of gravity to nearly zero and recover almost all of the blood from the surface upon which it had been deposited.

Volume of blood contained in each capillary tube was easily and accurately calculated from the length of the liquid and its previously measured diameter. Because of the wide range of standard volumes, as well as the anticipation that some very small bloodstains would be produced, three different diameter capillary tubes were employed. Two of these small glass tubes were commercially available having diameters of approximately 0.525mm and 0.725mm. In addition, glass tubes were drawn out to very fine capillaries having internal diameters of approximately 0.33mm. Regardless of which of the three capillary diameters was selected, each was accurately measured prior to being used to withdraw blood from a stain.

3) Standardization: Accuracy of the overall method for blood removal was established by placing known volumes of blood on a surface using automatic pipettes. Several Bio-Dynamics (R) automatic pipettes, having a capacity of from 10 lambda to 100 lambda, were used to dispense accurate blood volumes. Several known blood volumes were carefully deposited on various surfaces and then removed in the manner previously described. A diagrammatic representation of this procedure is shown as Figure #1. Whenever a bloodstain was elliptical

rather than round, the length and width were simply averaged to obtain the stain's "average diameter". Some very small drops of blood were projected onto surfaces intentionally at known angles but the volume of these drops was not known. Nevertheless, data obtained from these small elliptical bloodstains fit the working curve very well. This working curve is described in greater detail later under results in section three which follows.

IV) RESULTS:

Correlation between known, standard volumes, and the volume of blood actually removed from a non-porous surface is shown in Table I. It should be noted from this data that there is very little difference between the percentage of blood that was recovered from the four volumes of blood that had been deposited on a glass or Formica (R) surface. The average percentage recovery of 90.1% of blood deposited on a glass surface suggests that a correction factor of 1.1 must be used to estimate the volume of blood in a bloodstain that has been recovered from glass or other non-porous surfaces.

A similar correlation between known, standard volumes, and the volume of blood that was actually removed from a porous surface is shown in Table II. As would be expected, the amount of blood that was recovered from these bloodstains was considerably lower as blood simply soaked into the porous surface of the cardboard. As a result, a correction factor of 1.2 must be used to multiply the volume of blood recovered from this type of a surface when estimating the volume of blood that produced it.

A working curve was generated using the correlation of data from known blood volumes vs. bloodstain diameter, as well as the blood volume that was estimated using correction factors for any of the smaller bloodstains. Naturally, consideration was given to the type of surface upon which a bloodstain had been deposited. This curve is shown as Figure #2: Blood Volume as a Function of Stain Diameter. With reference to this figure, the relationship of any bloodstain diameter and the approximate volume of blood that was required to produce it may be easily estimated.

A more convenient expression of this relationship may be seen in Table III which lists the approximate blood volume that would be required to produce a specific bloodstain diameter. It should be remembered that while the nature of the surface may affect the amount of blood that could be removed from it, this is of little or no significance when estimating the volume of blood that would be required to produce a bloodstain of a certain size.

A more convenient expression of this relationship may be seen in Table III which lists the approximate blood volume that would be required to produce a specific bloodstain diameter. It should be remembered that while the nature of the surface may affect the amount of blood that could be removed from it, this is of little or no significance when estimating the volume of blood that would be required to produce a bloodstain of a certain size.

V) CONCLUSION:

It is concluded that if the diameter of a bloodstain is known, it is possible to estimate the volume of blood required to produce that stain with an accuracy of plus or minus ten percent from reference to either Figure 2 or Table III.

Application of information outlined in this article may be quite limited. The question of just how much blood might be required to produce a bloodstain of a specific size seems of little significance. Nevertheless, as was indicated in the introduction, it has been the experience of the senior author to have been asked this very question when giving testimony in court. Now, it is possible to answer this question with greater accuracy than in the past. It is the authors' hope that this information will be of value to other investigators during their study of bloodstain patterns and the presentation of their results in court. If so, then our efforts have been worthwhile.

VI) ADDENDUM:

Since writing this article and presenting it during the fifth meeting of the International Association of Bloodstain Pattern Analysts in Dallas, Texas on 1 December 1989, it is quite likely that the information herein contained may well be of considerable interest to many others. Those who utilize computer modeling to establish blood drop trajectories must know the mass of the drop that produced a specific bloodstain. By using either Figure 2 or Table III, it is possible to estimate the original blood volume that would have been required to produce a bloodstain of a given area. After this volume has been calculated, by simply using the density of human blood, it is possible to approximate the mass of the original blood drop. Such information should be applicable to the research of Podworney and Carter, whose paper was also presented at the Dallas meeting of IABPA, as well as to others who may be studying various computer applications to bloodstain pattern interpretation (3). It seems that we may have provided a convenient solution to a problem we did not know existed. Was this serendipity?

VII) REFERENCES:

(1) MacDonell, Herbert Leon, and Lorraine Fiske Bialousz, Flight Characteristics and Stain Patterns of Human Blood, Washington, D. C., United States Department of Justice, Law Enforcement Assistance Administration, National Institute of Law Enforcement and Criminal Justice, 1971, 77p.

(2) Griffin, Tom J., and Ross Garner, personal communication.

(3) Podworney, Edward J., and Alfred L. Carter, Computer Modeling of the Trajectories of Blood Droplets and Bloodstain Pattern Analysis with a PC Computer, Paper presented during the fifth meeting of the International Association of Bloodstain Pattern Analysts, Dallas Texas, 1 December 1989. ^E

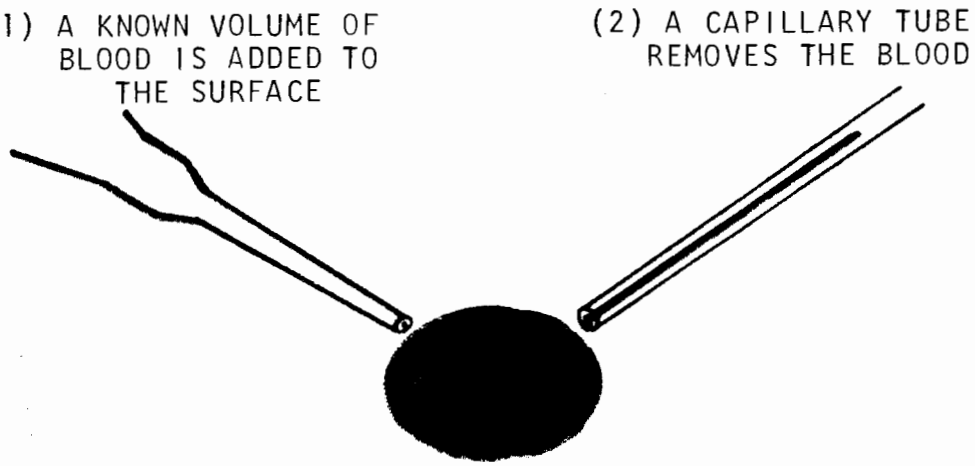

FIGURE 1: Procedure for adding and removing blood.

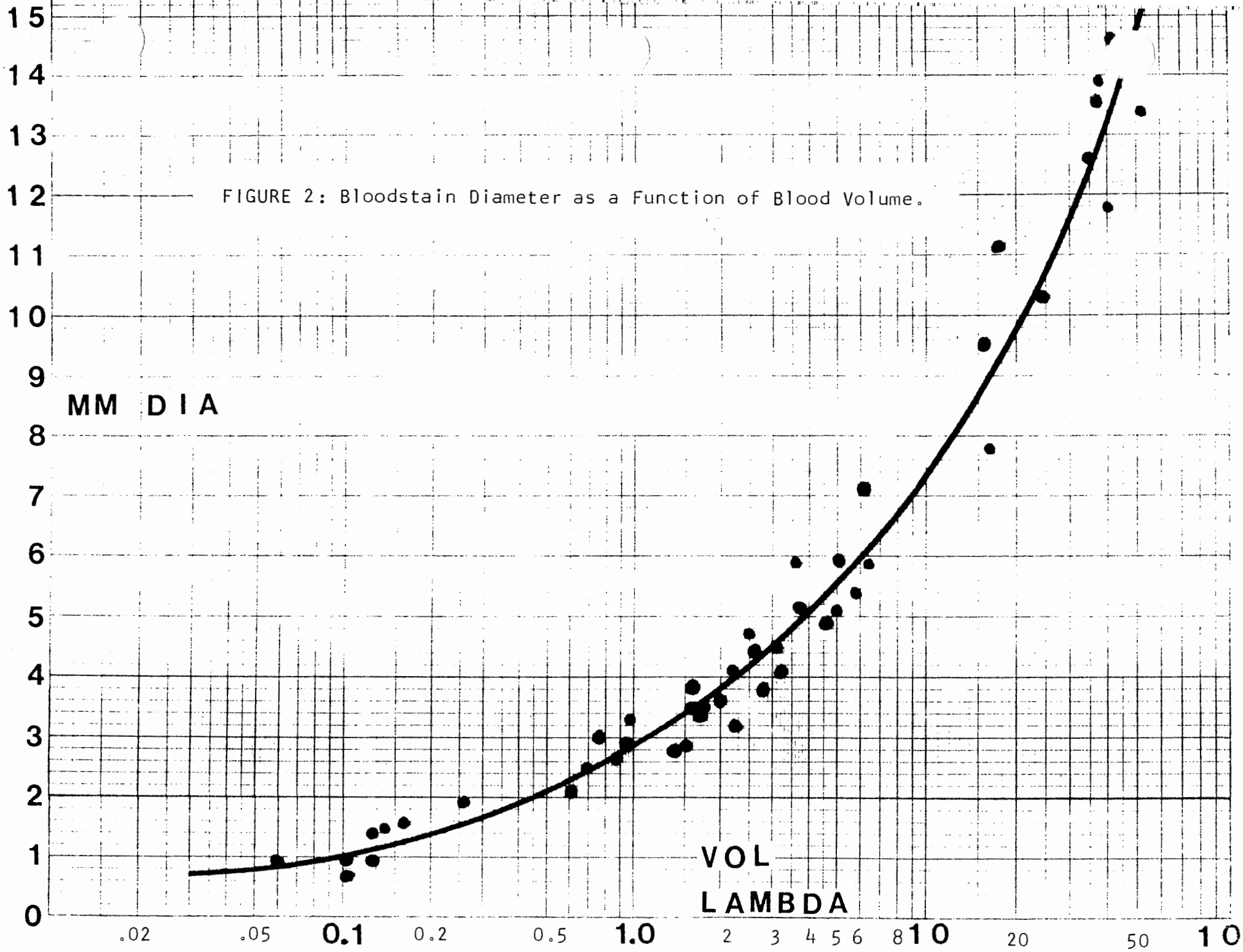

FIGURE 2: Bloodstain Diameter as a Function of Blood Volume.

TABLE I: Non-porous Surfaces (Glass/Formica)

Standard Volume Added	Average Volume Recovered	Percent Recovery*	Average Stain Diameter	Average Stain Thickness
10 lambda	8.85 lambda	88.5%	5.5mm	0.42mm
20 lambda	18.43 lambda	92.2%	7.0mm	0.52mm
25 lambda	22.43 lambda	89.7%	7.5mm	0.57mm
50 lambda	45.11 lambda	90.2%	8.9mm	0.80mm

*Since the average percent recovery was 90.1% a correction factor of 1.1 was used to increase the recovered volume to the original bloodstain volume.

TABLE II: Porous Surfaces (Cardboard)

Standard Volume Added	Average Volume Recovered	Percent Recovered*	Average Stain Diameter	Average Stain "Thickness"
10 lambda	7.51 lambda	75.1%	2.9mm	1.51mm
20 lambda	17.02 lambda	85.0%	4.3mm	1.38mm
25 lambda	22.70 lambda	90.8%	4.6mm	1.50mm

*Since the average percent recovery was 83.6% a correction factor of 1.2 was used to increase the recovered volume to the original bloodstain volume.

TABLE III: Blood Volume as a Function of Stain Diameter

Stain Diameter	Approximate Blood Volume
0.3 mm	0.07 lambda
0.5 mm	0.08 lambda
1.0 mm	0.10 lambda
1.5 mm	0.25 lambda
2.0 mm	0.45 lambda
2.5 mm	0.75 lambda
2.9 mm	1.00 lambda
3.0 mm	1.10 lambda
3.5 mm	1.60 lambda
4.5 mm	3.00 lambda
5.0 mm	3.80 lambda
6.0 mm	6.10 lambda
7.0 mm	9.00 lambda
8.0 mm	12.5 lambda
9.0 mm	16.5 lambda
10.0 mm	21.0 lambda
15.0 mm	51.0 lambda