TECHNICAL NOTE

Dale L. Laux,[1] *M.S. and James W. Wurster,*[2] *M.S.*

The Relative Indices of Efficiency for Selected Methods of Bloodstain Analysis

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ABSTRACT: Selected methods of analysis are compared with respect to man-hours, cost, and discrimination power. The methods are listed according to their efficiencies with Enzyme Group I System being the most efficient and Enzyme Group III System the least.

KEYWORDS: criminalistics, blood, electrophoresis, bloodstain, discrimination power

The forensic serologist is frequently faced with the job of distinguishing two or more blood samples. In recent years, several genetic markers have been found that are polymorphic and add information to well known markers such as the ABO blood groups. Most likely, in the years to come, more polymorphic genetic markers will be found which may eventually lead to the individualization of blood samples. However, many criminalistics laboratories will reach the point where practical constraints limit the number of genetic markers used. The purpose of this paper is to compare several of the currently used methods of blood analysis with respect to cost, time, and discrimination power.

Usefulness of Genetic Markers

Analysis of bloodstains may involve the detection of from one to a dozen or more genetic markers. The frequency of the genetic markers determined to be present in a bloodstain may be significant in eliminating or associating a given individual as the source of the stain. Every marker has a different potential for individualization. How useful is any one marker or combination of markers in distinguishing two blood samples? There are several measures to assessing individualization potential of various markers. The probability of a match (PM) is the probability that two randomly selected samples will match identically with respect to the markers used [*1*]. The discrimination power (DP) is defined as the probability that two randomly selected samples will be distinguishable by one or more of the genetic markers, used, $DP_n = 1 - (PM_1)(PM_2)(PM_3) \ldots (PM_n)$ where n equals the number of genetic markers

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[1]Criminalist, Ohio Bureau of Criminal Identification and Investigation, East Central Laboratory, Cambridge, OH.

[2]Criminalist, Ohio Bureau of Criminal Identification and Investigation, Northeast Laboratory, Richfield, OH.

used [2]. Values for the probability of a match and discrimination powers for a number of genetic markers are found in Table 1.

The higher the discrimination power, the greater chance of distinguishing two samples. Using different genetic markers in concert, one can achieve a high discrimination power. For example, using the ABO system alone, one can distinguish two random samples 60% of the time. However, using the ABO system with the genetic markers PGM_1, EsD, and GLO-I, the discrimination power increases to approximately 0.95, and two random samples can be distinguished 95% of the time.

What genetic markers should or should not be used in analyzing stains? Naturally it is up to the individual forensic serologist to choose systems that will yield useful information depending on size and age of the sample, suspected source, proficiency of examiner, laboratory budget, caseload, and so forth. To aid in the selection of genetic markers to be used, the following formula was developed:

$$\text{man-hours per analysis} \times \text{cost per analysis} \times 1/\text{DP of the marker(s)} = \text{RIE}$$

where RIE equals the relative index of efficiency. Obviously, the lower the RIE value, the more efficient the analysis.

Methods

The amount of time required to perform a certain analysis was determined by performing the required steps, that is, preparing the buffers and specimens, making the analysis and interpreting the results [4], at a moderate rate of speed. Long incubation periods or run times were not included in the determination as other duties could be performed simultaneously.

The costs of materials required for a certain analysis were determined by listing *consumable* materials such as pipette tips, centrifuge tubes, reagents, and so forth, and recording their prices from various sources.[3] The cost of reusable equipment such as power supplies, cooling circulators, electrophoresis tanks, and so on, was not included in this determination.

TABLE 1—*Probability of matches (PM values) and discrimination powers (DP values) for selected genetic markers.*[a]

Genetic Marker	PM	DP
ABO	0.40	0.60
Esterase D (EsD)	0.65	0.35
Phosphoglucomutase (PGM_1)	0.48	0.52
Gloxylase-I (GLO-I)	0.39	0.61
Erythrocyte acid phosphatase (EAP)	0.32	0.68
Adenosine deaminase (ADA)	0.79	0.21
Adenylate kinase (AK)	0.89	0.11
Phosphoglucomutase subtype (PGMs)	0.25	0.75
6-Phosphogluconate dehydrogenase (6PGD)	0.92	0.08
Haptoglobin (Hp)	0.39	0.61
Group specific component (Gc)	0.43	0.57
Transferin (TF)	0.98	0.02
Peptidase A (PEPA)	0.72	0.28
Carbonic anhydrase II (CA II)	0.69	0.31
Glucose-6-phosphate dehydrogenase (G6PD)	0.58	0.42
Hemoglobin (Hb)	0.81	0.19

[a]PGM subtype from data in [5], glucose-6-phosphate dehydrogenase from data in [6], and all other data in [7].

[3]Sources included SERI, Ortho, Sigma, Fisher, Markson, and Cal Biochem.

The specific methods of bloodstain analysis compared were the following:

(1) ABO typing by absorption elution [*3*];
(2) Group I separation of EsD, PGM_1, and GLO-I [*4*];
(3) PGM subtyping [*5*];
(4) Group II separation of ADA, AK, and EAP [*4*];
(5) Group III separation of Hp, Gc, and TF [*4*]; and
(6) Group IV separation of PEPA, CAII, G6PD, and Hb [*3*].

Results

Comparing selected methods of bloodstain analysis with respect to time and cost, along with discrimination power yields some interesting information. Table 2 lists the analytical methods in the order of their efficiency. It can be seen from this table that when considering man-hours, cost, and discrimination power, Group I, PGM subtyping, and Group IV analyses are more efficient than absorption elution typing.

Also, while Group II and Group III provide relatively high discriminatory powers, when cost and time are considered, they are less efficient than other analyses.

Discussion

A comparative examination of currently used methods of bloodstain analysis has been presented. RIE was determined for each of the various methods.

The results indicate that using Group I, PGM subtyping, and Group IV methods in addition to absorption elution present a very informative cost effective gamet of study. In addition, Group I, PGM subtyping, and Group IV methods are applicable to semen analysis. Used in concert, Group I, PGM subtyping, Group IV, and absorption elution methods present a discrimination power of 0.997. If Group II and Group III analyses are performed in addition to these, the discrimination power increases to 0.999. Each lab must decide whether the small increase in discrimination power is worth the added time and expense of the analyses.

Every case submitted to a forensic science laboratory is unique and must be given individual consideration. Before any analyses of bloodstains are performed, variables such as sample size, age of stain, laboratory budget, and caseload must be given careful thought. Group II and Group III analyses offer a great deal of information, however, they are not as efficient as other methods of analysis. They could possibly be used in certain cases to supplement other information.

Other methods of analysis could certainly be compared along with the methods examined here by using the formula for determining RIE. Inflation will undoubtedly cause an increase in the cost of supplies, however, it should affect each analysis relatively the same. Relative indices of efficiency could be prepared by laboratories yearly to investigate any selected cost or time changes in the methods they use. Also, relative indices of efficiency could be

TABLE 2—*Man-hours, cost, and RIEs for selected analytical methods.*

System	Man-Hours	Cost, $	RIE
Group I	2.0	1.52	3.46
PGM subtyping	1.5	1.81	3.62
Group IV	1.5	2.22	4.34
ABO (absorption elution)	1.5	3.07	7.67
Group II	2.0	3.29	8.49
Group III	2.0	5.69	13.61

calculated for newly developed methods of bloodstain analysis to determine their potential for routine use.

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Address requests for reprints or additional information to
Dale L. Laux
Ohio Bureau of Criminal Identification and Investigation
East Central Laboratory
Court House Annex
Cambridge, OH 43725