The Standardized Paternity Index for the Statistical Evaluation of Blood Group Findings in Paternity Testing

W. Martin

Aus dem Bundesgesundheitsamt

Robert Koch-Institut

Berlin

Zusammenfassung

Die Standardisierung des Paternity Index basiert auf den Irrtumswahrscheinlichkeiten nach Schulte Mönting und Walter. Durch die vorgeschlagene Standardisierung wird neben der vollen Information der Blutgruppenbefunde auch der Untersuchungsumfang berücksichtigt. Die Interpretation des rechnerischen Ergebnisses erfolgt durch verbale Prädikate. Neben der wesentlichen Tatsache, daß der Untersuchungsumfang berücksichtigt wird, ist ein Hauptvorteil dieses Vorgehens, daß das rechnerische Ergebnis in die Gerichtsentscheidung nur durch den PI und sein verbales Prädikat eingeht und nicht durch mitunter relativ hohe Prozentwerte, die von Laien falsch verstanden werden können. Beim gegenwärtigen Stand reicht bei den meisten Fälle die alleinige Verwendung der Ausschließungschance für Nichtväter (A) aus. Bei einem Untersuchungsumfang von 25 Systemen einschließlich HLA wird bei über 90 % der Mutter-Kind-Paare ein Wert von A = 99,73 % erreicht oder überschritten, was den Beweis der Vaterschaft eines Mannes allein durch die Tatsache des Nicht-Ausschlusses bedeutet.

Advances in Forensic Haemogenetics 1
Edited by B. Brinkmann and K. Henningsen

Summary

The standardization of the paternity index (PI, X/Y) is based on the probabilities of error according to Schulte Mönting and Walter. By using the suggested standardization, the test volume is taken into account including the full information of the blood group findings. The interpretation of the mathematical result is given by verbal predicates.Besides the essential fact that the test volume is taken into account, the most important advantage of this procedure is that the mathematical result is included in the court decision only by the PI and its verbal predicate and not by sometimes relatively high percentages, that may be misunderstood by laymen. At the present stage, the use of the chance of exclusion for non-fathers (A) alone is sufficient in most cases. At a test volume of 25 systems including HLA, more than 90 % of the mother/child pairs reach or exceed a value of A = 99,73 %, indicating proof of paternity by the fact of non-exclusion of a man alone.

For the statistical evaluation of blood group findings in paternity testing, the likelihood ratio Y/X (L) or X/Y (PI) provides the full information on blood testing. The X/Y ratio indicates the relation of the frequency of begetters to that of any (unrelated) man. PI indicates how many times more frequently the phenotype of the alleged father occurs in true father trios than in non-father trios. It is possible, therefore, by means of this ratio to assign an alleged father in the different groups (begetters or any unrelated man). This assignment has risks of error: it may happen that any man can, by mistake, be taken as begetter or a begetter by mistake as any unrelated man.

The likelihood ratio alone or its transformation to W (according to Essen Möller - Hummel) do not allow a realistic statement on the probabilities of error for the alternatives paternity or non-paternity, respectively. The probabilities of error can only be stated according to Schulte Mönting and Walter (based on the Neyman-Pearson principle).

Recent results showed that the probabilities of paternity according to W lead - at a great volume of tests - to values which may not be regarded as realistic in a single case. This is probably one of the main reasons why X/Y (PI) is more and more used as parameter. In this way the suggestive effect of high values of percent can be avoided without loss of information. In general, PI corresponds better to the common understanding than L (Y/X), since the chance to have to deal with a true father rises with increasing values.

The method for the statistical evaluation of blood group findings developed by Schulte Mönting and Walter in 1972, delivered for the first time the possibility to record probabilities of error without using Bayes theorem. Hereby, the full information of the likelihood-ratio X/Y is involved in the calculation. In this method, the distributions of the likelihood ratio are seen in special defined collectives or partial collectives, respectively. The knowledge of these distributions and the consideration of the area or partial area under the distribution make it possible to determine limits, the exceeding of which allows the indication of probabilities of error for correctness or incorrectness of certain hypotheses. The consideration of the area must be regarded as an essential and pregnant completion to the punctual statement based on Bayes' theorem. This theorem starts out from, in a single case, an unprovable presumption that an alleged father has equal (some times also unequally shifted but always to 100 % complementing) chances for or against paternity. The decisive fact of the method developed by Schulte Mönting and Walter, based on the Neyman-Pearson principle, is that the number of systems tested is considered in this calculation for the first time. The number of systems tested stays disregarded in the interpretation of the W value, while at equal PI values the probabilities of error change with the number of systems tested.

The addition of further systems of genetic markers shifts the summation distributions of the log X/Y values more and more into the region of positive values. Moreover the distribution curves assimilate more and more so that the differentiation between true fathers and not excluded non-fathers becomes more and more difficult.

Hence. it follows that on an average W increases for all not excluded men, independent of their being fathers or not. Consequently, the requirements for the height of the W value have to increase with increasing number of systems tested, corresponding to the probabilities of error changing at equal PI values with the number of systems tested. A certain probability of error being attributed to a PI value at a fixed number of systems has to be allocated to a continually increasing PI value with increasing number of systems.

Consequently, it has to be demanded that the paternity index has to be standardized in dependency of the number of systems tested. Hereby, the use of the W value is no longer necessary and the complete information of the findings is considered including the volume of tests. The tables on the probabilities of error according to Schulte Mönting and Walter as to Umbach and Walter are the basis here. The table on a volume of tests for 15 systems of the German guidelines for paternity testing is the starting point. At a higher volume of tests, the likelihood ratio PI is multiplied by a corrective factor calculated from the distribution tables with the effect that the test volume is considered in the evaluation and the calculated values become comparable with those calculated in cases with a different number of systems tested.

A PI value of 400 (L = 0.0025, W = 99.75 %, PEF = 0.15 %) in the 15 systems of the German guidelines is the starting point for the corrective factor (CF) which is here 1. With an increasing volume of tests the value of PEF * (0.15 %) is allocated to a continually increasing PI value. As a result of this, the CF is calculated

* PEF = probability of error for the assumption of fatherhood

as follows:

$$CF = \frac{PI\ 400\ \text{(with PEF 0.15\% with 15 systems)}}{PI\ X\ \text{(with PEF 0.15\% with Y systems)}}$$

The CF for the increasing volume of tests is summarized in Table 1 and graphically shown in Fig. 1 . It can be seen that the CF is just slightly changed at a volume of tests from 23 to 24 systems. The CF will, therefore, remain constant with the addition of further systems. An example for a result of a case is given in Table 2. .

The PI*s is the first parameter in the statistical evaluation of blood group findings in Paternity Testing giving complete information of the likelihood ratio and, moreover, regarding the test volume based on the probabilities of error according to Schulte Mönting and Walter. At the same time, the statement of high percentage values can be avoided, which might easily pretend a non existing safety to a layman.

With PI*s, a parameter is given which is only understandable for the layman by a corresponding explanation of the expert. The result influences the court decision only by the expert's professional explanation but not by possibly misleading relatively high values of percent. The best way to give this explanation is by verbal predicates with four ranges as listed in Table 3 . The limit of the standardized PI is given but neither a certain probability of error nor a W value.

The most important aspects are emphasized as follows:

1. By using the Paternity Index as parameter, the indication of plausibilities of paternity in percent can be renounced without loss of information.
2. By standardization of the PI in the proposed way, the test volume is also taken into consideration.

3. The employment of the proposed verbal predicates delivers the explanation of the mathematical result.

Finally, it can be stated that the use of the likelihood ratio in most cases is no longer necessary. At a test volume of about 25 informative systems including HLA (as it is performed in our and in many other laboratories), the chance of exclusion for non-fathers reaches values exceeding 99.73% in more than 90% of the cases. In all these cases, the proof of paternity can be based on the fact of non-exclusion alone. The power of the test, then, is so high that the possible error (1-A. non-exclusion of a non-father by accident) is minimal and can be neglected. Because of the power of the test, this is also valid. if PI*s does not reach or exceed a value of 400.

Consequently, our statistical expertises are given as follows:

1. Calculation of A: if A >= 99.73%, report of A alone with the corresponding verbal predicate.
2. If A < 99.73%, calculation of PI*s, if PI*s >= 400, report with the corresponding verbal predicate.
3. If A < 99.73% and PI*s < 400, recommendation of further serological investigations, if possible.

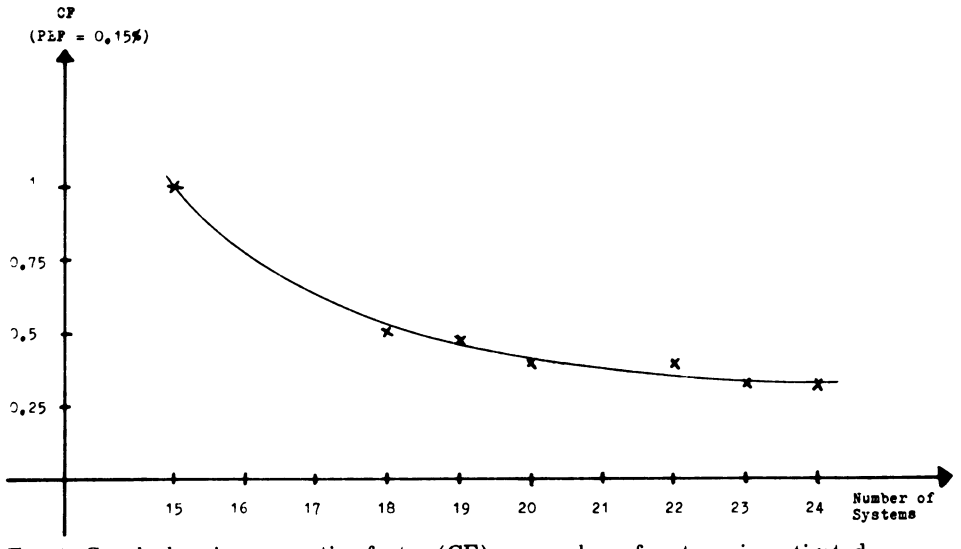

Fig. 1. Graph showing corrective factor (CF) vs. number of systems investigated.

TABLE 1

CF, PEF = 0.15%

Mean value according to the curve shown

No. of Systems	*CF*
15	1
16	0.78
17	0.63
18	0.53
19	0.46
20	0.41
21	0.38
22	0.35
23	0.34
24	0.33

Table 2

Case result, 25 systems including HLA

PI = 2711 L = 0.000369

PI*s = 904

(W*s = 99.889%) W = 99.96%

Table 3

Verbal Predicates PI*s - A

I A >= 99,73 %
PI*s >= 400

Paternity practically proved

II 99,73 % > A > 90 %
400 > PI*s > 10

Indication of paternity

III A < 90 %
PI*s < 10

The statistical evaluation of the blood group findings did not deliver usable contributions to the ascertainment of paternity.