THE SCOPE OF BLOOD GENETIC MARKER INVESTIGATIONS IN PATERNITY TESTING IN CHINESE AND MALAYS

By B. R. Hawkins

SYNOPSIS

The chance of excluding from paternity a falsely accused Chinese man and a falsely accused Malay man by using a number of blood genetic marker systems have been calculated. Using the ABO, Rhesus and MNSs systems, the combined chances are 46·4% for a Chinese and 50·2% for a Malay. When serum protein and red cell enzyme systems are included, the chances increase to approximately 76%. The chances may be increased by testing for haemoglobin variants, by red cell typing for the Diego (Di^a) antigen, and by testing for phenotypes other than Gm(a) in the Gm system. The Kell system may in some circumstances provide evidence in favour of paternity.

INTRODUCTION

The practice of investigating the distribution of blood genetic markers in the parties involved in disputes of paternity has become well established in attempting to resolve such situations. Often, however, the parties require to know the measure of success that the investigation is likely to achieve before they consent to submit themselves for blood tests and so it is useful to have this information available. For a caucasian population, Race and Sanger (1968) have calculated that when blood from the mother, child, and putative father in a paternity dispute is grouped for seven red cell antigen systems, the chance that a wrongly accused man will be excluded from paternity is about 62%. Welch (1973) has further calculated that when the blood is tested additionally for three serum protein systems and six red cell enzyme systems, the chance of exclusion is increased to 89%. It is well known that the frequencies with which specific blood genetic markers occur in one ethnic group are often considerably different in other ethnic groups. Hence the chances of excluding a falsely accused caucasian from paternity may not necessarily be the same as the chance of excluding a non-caucasian. The chances have, therefore, been calculated for a Chinese and a Malay population.

APPLICATION OF BLOOD GENETIC MARKERS TO PATERNITY TESTING

The measure of success in excluding a falsely accused man from paternity of a given child by use of blood genetic marker studies is dependent upon two main factors. Firstly it depends upon the number of genetic marker systems used in the investigation, and secondly upon the frequency with which variant forms of the individual genetic markers occur in the population. The application of genetic markers to paternity testing has been discussed by Dodd (1969) and so only a brief illustration of these criteria will be given here. In the case of a group O mother with a group A child, for instance, the mother is of genotype *OO* and may only contribute gene *O* to the child, hence the A component of the child's blood must be of paternal origin. However, since approximately 45% of Western European caucasians are of group A or AB, 45 out of any random group of 100 caucasian males would possess an *A* gene and could not be excluded from paternity when the ABO system is used alone. If the child was found also to possess the Kell (K) antigen, and this antigen was not present in the mother's blood, then it, too would have to be of paternal origin. Since only about 10% of the caucasian population possess the Kell antigen, only 10% of a random group of 45 men would be expected to possess this antigen. Thus, only 10% of the 45 group A men who could not originally be excluded from paternity would be expected to also possess the Kell antigen. Hence, only about 4·5% of any randomly selected group of men could be the father in this particular case. As more genetic marker systems are included, so the chance of excluding a 'non-father' increases.

The chances of exclusion offered by a particular system may be calculated if the gene frequencies pertaining to that system are known for the population under consideration. This is because the gene frequencies are, in fact, expressions of the probability with which the specific characteristics occur in the population. Table I presents the gene frequencies which appear to best represent the range of

Department of Human Biology, The John Curtin School of Medical Research, Australian National University, P.O. Box 334, Canberra City, Act 2601, Australia.

B. R. HAWKINS.

TABLE I

FREQUENCIES OF BLOOD GENETIC MARKERS IN CHINESE AND MALAYS

Marker system	Alleles	Gene Frequencies Chinese	Malays
ABO	*A*	·167	·175
	B	·166	·205
	O	·667	·620
Rhesus	R_1—*CDe*	·757	·766
	R_2—*cDE*	·191	·152
	R_z—*CDE*	·010	·010
	R_0—*cDe*	·021	·024
	r —*cde*	·021	·048
MNSs	*MS*	·030	·073
	Ms	·540	·514
	NS	·003	·041
	Ns	·427	·372
Kell	*K*	0	·002
Duffy	Fy^a	·910	·940
Gm	Gm^a	1·000	1·000
Haptoglobin	Hp^1	·30	·24
	Hp^2	·70	·76
Gc	Gc^1	·77	·84
	Gc^2	·23	·16
Phosphoglucomutase (PGM)	PGM^1	·75	·76
	PGM^2	·25	·24
6-Phosphogluconate dehydrogenase (6-PGD)	PGD^A	·93	·94
	PGD^B	·07	·06
Adenylate kinase (AK)	AK^1	1·00	·98
	AK^2	0	·02
Acid Phosphatase	p^a	·21	·34
	p^b	·79	·66

frequencies reported for Chinese and Malays (reviewed by Hawkins, 1973a, 1973b). Using the figures in Table I, the chances of excluding a falsely accused man have been calculated for Chinese and for Malays and are shown in Table II. The cumulative chances are also shown in Table II together with the exclusion chances for a caucasian population. The figures for caucasians were kindly provided by Dr. S.G. Welch of the Department of Biochemistry, The London Hospital Medical College.

There is extensive literature on the chances of excluding a falsely accused man from paternity of a particular child by using genetic marker investigations, but only in the case of the Rhesus system is the calculation particularly complex. For the ABO system, the probability of obtaining an exclusion of paternity was calculated by the method of Wiener *et al* (1930). The probability is given by the expression:—

$$P_{A,B} = p(q+r)^4 + q(p+r)^4 + pqr^2(p+q) + 2pqr^2$$

where p, q, and r, represent the frequencies of the genes *A*, *B* and *O* respectively.

Since there is now no difficulty in obtaining anti-s serum the calculation for the MNSs system was based upon the use of four antisera, anti-M, anti-N, anti-S and anti-s, using the method given by Wiener (1952). In this case, the probability is given by the expression:—

$$P_{M,N,S,s} = mn(1-mn) + xy(1-xy) - \tfrac{1}{2}(a^2+b^2+c^2+d^2+1)(a^2d+ad^2+b^2c+bc^2) + abcd$$

where m and n represent the frequencies of genes *M* and *N* respectively; x and y the frequencies of genes *S* and *s*; and a, b, c, and d, the frequencies of the gene complexes *MS*, *NS*, *Ms* and *Ns*, respectively.

In the case of the Rhesus system, the calculation was based upon the use of four antisera, anti-D, anti-C, anti-E, and anti-c, using the method of Boyd (1955). This method involves first calculating the frequency with which children of various Rhesus phenotypes are born to mothers of various phenotypes. It is then necessary to know for a man of given phenotype which combinations of mother and child would exclude paternity. Boyd's table giving this information has been reprinted by Race and Sanger (1968). The required probability is obtained by adding, for all combinations of mother and putative father, the frequencies with which children occur who exclude the putative father from paternity. The calculations are considerably simplified by assuming that the Rhesus complexes *cdE*, *Cde*, and *CdE*, do not occur in Chinese and Malays. Although this assumption is known not to be true, the very low frequencies with which these complexes occur do not make any significant contribution to the overall probability of exclusion offered by the Rhesus system. Since this probability has been based upon the use of four antisera, it may be somewhat invalid to compare the value with that of 0·280 given by Welch (1973) for a caucasian population based on the additional use of anti-e and anti-C^w sera. However, the use of anti-e does not appear to significantly increase the probability of exclusion as shown when the figure of 0·250 calculated by Boyd (1955) on the basis of tests with only four antisera is compared with the figure of 0·280 obtained when six sera are employed. Moreover, since the C^w antigen appears to be absent or rare in Chinese and Malays (Hawkins and Simons, unpublished observations) the additional use of

TABLE II

CHANCES OF EXCLUDING A FALSELY ACCUSED MAN FROM PATERNITY IN THREE ETHNIC GROUPS

Marker System	Chinese		Malays		English*	
	Individual Chances	Cumulative Chances	Individual Chances	Cumulative Chances	Individual Chances	Cumulative Chances
ABO	·190	·190	·196	·196	·176	·176
Rhesus	·162	·321	·166	·329	·280	·406
MNSs	·211	·464	·258	·502	·321	·597
Kell	0	·464	0	·502	·033	·610
Duffy (anti-Fy^a)	0	·464	0	·502	·048	·629
Gm (Gm^a)	0	·464	0	·502	·065	·653
Gc	·146	·542	·116	·560	·145	·703
Haptoglobin	·166	·618	·149	·626	·175	·755
PGM	·152	·676	·149	·682	·145	·791
6-PGD	·061	·696	·053	·699	·025	·796
AK	0	·696	·019	·705	·045	·805
Acid Phosphatase	·138	·738	·174	·756	·210	·846

* Figures kindly supplied by Dr. S. G. Welch.

anti-C^w would be of no value of obtaining an exclusion of paternity.

For marker systems which are essentially bi-allelic and co-dominant, the probability of excluding a 'non-father' is given by the expression:— $P_{v,w} = vw\ (1 - vw)$ where v and w are the frequencies of the two hypothetical alleles V and W respectively.

For a system in which only one antiserum is available to demonstrate a bi-allelic dominant-recessive situation (eg. Fy^a, K) the probability is given by the expression:—

$P = r^4 - r^5$ where r is the frequency of the recessive gene.

The calculation for the cumulative probability of exclusion for a number of marker systems is best illustrated by an example. The combined chance provided by the ABO, Rhesus, and MNSs systems in a Chinese population, for example, is given by:—

$P = 0{\cdot}211\ (1 - 0{\cdot}321) + 0{\cdot}321 = 0{\cdot}464$

From Table II it is seen that by using the ABO, Rhesus, MNSs, Kell and Duffy systems the maximum chance of excluding a falsely accused Chinese is 46·4% and, for a falsely accused Malay, 50·2%. These figures compare somewhat unfavourably with the figure of 62·9% for a caucasian 'non-father' when the same systems are used. If facilities are available to proceed with grouping for two serum protein systems, Gc and Haptoglobin and for the four red cell enzyme systems listed, a reasonably acceptable figure of approximately 76% compared with 84·6% in a caucasian population is obtained. It should be emphasised, however, that these probabilities may not necessarily apply if the mother cited a man of different ethnic type to herself.

OTHER CONSIDERATIONS

Notwithstanding the fact that the chance of success in excluding a falsely accused man is increased by 50% by testing for the serum protein and red cell enzyme systems quoted, it is unlikely that facilities would be readily available for the provision of these tests. However, the exclusion chances may be increased by testing for marker systems that are particularly appropriate in Mongoloid populations. Approximately 5% of Malays, for example, possess Haemoglobin E. In addition, the Diego blood group system could usefully be included in the range of tests as the Di^a antigen occurs in about 5% of Chinese and Malays. Furthermore, although the Gm system is of no value when the tests are restricted to the identification of the Gm(a) phenotype, extension of the tests to identify other Gm phenotypes can result in an exclusion probability comparable with that provided by the ABO and MNSs systems. Mention should also be made that whilst the Kell and Duffy blood group systems are of negligible value in excluding a putative father, there is still some justification in retaining the systems in paternity testing. Although the Kell antigen is rare in Malays, its presence has been demonstrated by Case and Lopez (1973) in 2 out of 437 Malays

tested in Kuala Lumpur. If the child and the putative father both possessed such a low frequency antigen which was absent from the mother, the chance that the antigen had been contributed to the child by somebody other than the putative father would be extremely small. This situation could, therefore, provide valuable evidence in favour of the man's paternity.

REFERENCES

1. Boyd, W.C.: "Chances of Excluding Paternity by the Rh Blood Groups." Amer. J. Hum. Genet., 7, 229-235, 1955.
2. Case, J. and Lopez, C.G.: Personal communication, 1973.
3. Dodd, B.E.: "The scope of blood grouping in the elucidation of problems of paternity." Medicine Sci. Law, 9, 56-60, 1969.
4. Hawkins, B.R.: "The Distributions of Blood Genetic Markers in the Malay Populations of the Malay Peninsula." In preparation, 1973.
5. Hawkins, B.R.: "The Distribution of Blood Genetic Markers in Immigrant Chinese Populations." In preparation, 1973.
6. Race, R.R. and Sanger, R.: "Blood Groups in Man." 5th Ed., Blackwell, Oxford and Edinburgh, 1968.
7. Welch, S.G.: Personal communication, 1973.
8. Wiener, A.S.: "Heredity of the M-N-S Blood Types. Theoretico-Statistical Considerations." Amer. J. Hum. Genet., 4, 37-53, 1952.
9. Wiener, A.S., Lederer, M. and Polayes, S.H.: "Studies in Isohemagglutination IV: On the chances of proving non-paternity: with special reference to blood groups." J. Immunology, 19, 259-282, 1930.