Glucose-6-phosphate dehydrogenase deficiency in Chinese

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SYNOPSIS In a Chinese population 1,000 full-term male neonates and a further 117 jaundiced neonates of both sexes were studied in an investigation of the frequency of deficiency of erythrocyte glucose-6-phosphate dehydrogenase (G6PD). This enzyme was found to be deficient in 3.6% of male neonates. Correlation of the results with the birthplace of the 602 mothers who were known to come from Kwangtung province showed no significant differences in the frequency of the deficiency between certain parts of the province.

The deficiency of G6PD in hemizygous males is profound but it is not associated with erythrocyte acid monophosphoesterase deficiency in Chinese in Hong Kong. The G6PD deficiency accounts for 15.4% of all the 117 cases of neonatal jaundice. The relative importance of G6PD deficiency as a cause of neonatal jaundice does not differ materially in male and female mutants. Neonatal jaundice can occur in all genotypes of G6PD mutation in Chinese.

Glucose-6-phosphate dehydrogenase (G6PD) deficiency is one of the most prevalent and clinically heterogeneous of the genetically determined enzyme disorders in man. In widely diverse ethnic groups it varies in incidence and manifestations (Marks, 1964), but the mechanism responsible for these disparities is unknown. They may reflect fundamental differences in disordered structure and synthesis of G6PD among different races and individuals (Kirkman, Schettini, and Pickard, 1964).

Chan, Todd, and Wong (1965) demonstrated that the severity of G6PD deficiency and the extent of cellular involvement are similar in Chinese and Caucasians. The enzyme defect is associated with neonatal hyperbilirubinaemia, congenital non-spherocytic haemolytic anaemia and favism in Chinese (Jim and Chu, 1963; Naiman and Kosoy, 1964; Yue and Strickland, 1965), but the clinical and biochemical characteristics of G6PD deficiency have not been fully investigated in this race as yet.

This report is a study of the incidence and severity of G6PD deficiency among the neonatal male Chinese population of Hong Kong and of the relative importance of the enzyme defect in causing neonatal jaundice. The activity of erythrocyte acid monophosphoesterase (AMPE) in neonates with normal G6PD activity is compared with that of G6PD-deficient neonates.

MATERIAL AND METHODS
One thousand full-term neonates delivered consecutively in the Queen Mary Hospital, Hong Kong, were studied. A further group of 117 neonates of both sexes admitted on account of jaundice to the paediatric wards of the Queen Mary Hospital was also studied: the second group included some babies from the first group. All the babies were Chinese. Erythrocyte G6PD activity was screened by the methaemoglobin reduction test (Breuer, Tarlov, and Alving, 1962) and positive results in this test were checked by the brilliant cresyl blue test (Motulsky and Campbell-Kraut, 1961). Actual activity of G6PD was assayed by Prankerd’s modification of the Hornberg and Horecker spectrophotometric determination of the reduced nicotinamide adenine-dinucleotide-phosphate generation rate (Prankerd, 1962). Enzyme activity was expressed as units of change in optical density per minute per gram of haemoglobin (U.O.D. 340 mμ/min./g. haemoglobin).

The activity of erythrocyte AMPE was assayed by the method of King, Wood, and Delory (1945) as slightly modified by Oski, Shahidi, and Diamond (1963), the substrate, disodium phenylphosphate, being used in a concentration of 1.11 g./100 ml. instead of 0.01 M as in the original method. The enzyme activity was expressed as units of milligrams of phenol hydrolysed per hour per...
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The results of investigating the families of 13 jaundiced and six spontaneously delivered G6PD-deficient neonates are summarized in Table I, and the enzyme activities in the members of six G6PD-deficient neonates’ families are illustrated in Figure 1.

**TABLE I**

**INHERITANCE PATTERN OF G6PD DEFICIENCY IN CHINESE NEONATES**

<table>
<thead>
<tr>
<th>Name</th>
<th>Age at Examinaton</th>
<th>Father</th>
<th>Mother</th>
<th>Patient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LYKF</td>
<td>N.S.D.</td>
<td>Hetero</td>
<td>Hemi</td>
<td></td>
</tr>
<tr>
<td>TYL</td>
<td>N.S.D.</td>
<td>Hetero</td>
<td>Hemi</td>
<td></td>
</tr>
<tr>
<td>HSL</td>
<td>N.S.D.</td>
<td>S.D.</td>
<td>Hetero</td>
<td>Homer Hemi</td>
</tr>
<tr>
<td>MN</td>
<td>N.S.D.</td>
<td>S.D.</td>
<td>Hetero</td>
<td>Hemi</td>
</tr>
<tr>
<td>CYS</td>
<td>N.S.D.</td>
<td></td>
<td></td>
<td>Homer Hemi</td>
</tr>
<tr>
<td>HWS</td>
<td>30 days</td>
<td>Hemi</td>
<td>Hetero</td>
<td>Hemi</td>
</tr>
<tr>
<td>HCH</td>
<td>10 days</td>
<td>Hemi</td>
<td>Hetero</td>
<td>Hemi</td>
</tr>
<tr>
<td>NKW</td>
<td>6 days</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
</tr>
<tr>
<td>CYT</td>
<td>6 days</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
</tr>
<tr>
<td>CWL</td>
<td>35 days</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
</tr>
<tr>
<td>CHC</td>
<td>4 days</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCK</td>
<td>6 days</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
</tr>
<tr>
<td>WYM</td>
<td>6 days</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
</tr>
<tr>
<td>YWB</td>
<td>11 days</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
</tr>
<tr>
<td>TWW</td>
<td>10 days</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
</tr>
<tr>
<td>CMY</td>
<td>8 days</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
</tr>
<tr>
<td>LMW</td>
<td>8 days</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
<td>Neonatal jaundice</td>
</tr>
</tbody>
</table>


Females giving a positive result in screening tests but retaining some activity as shown by actual determination were considered to be partially deficient in the enzyme and were classified as heterozygotes of the abnormal G6PD gene: the enzyme level of 20 heterozygous female (16 mothers and four neonates) studied ranged from 4-0 to 4-9 U.O.D. 340 mμ/min./g. haemoglobin with a mean of 4-48 ± 0-48 U.O.D. 340 mμ/min./g. haemoglobin. Females showing a positive result in screening tests and no enzyme activity on actual determination were considered to be completely deficient in this enzyme and were classified as homozygotes of the abnormal G6PD gene. The results of familial investigation confirm that this enzyme defect is inherited as an X-linked trait in Chinese: 16 out of 18 mothers studied were identified as heterozygotes and two homozygotes of the abnormal G6PD gene while three out of the 18
facilitates the exchange and metabolism of certain substances in the body, including hemoglobin. The study of G6PD activity in neonates has revealed that it is lower in G6PD-deficient neonates compared to normal neonates. This difference is observed even in the slow and fast G6PD phenotypes. The enzyme deficiency is found in both Chinese and Caucasian populations, but the prevalence varies among different ethnic groups. The difference in G6PD activity between normal and deficient neonates suggests that this enzyme plays a crucial role in maintaining the proper function of red blood cells, especially in conditions where hemolysis is present.

**DISCUSSION**

Racial differences in clinical and biochemical characteristics of G6PD deficiency have been known for a long time. Neonatal hyperbilirubinemia, congenital nonspheroicytic jaundice, and kernicterus are well-documented complications associated with G6PD deficiency. The enzyme deficiency is found in both Chinese and Caucasian populations, but the prevalence varies among different ethnic groups. The difference in G6PD activity between normal and deficient neonates suggests that this enzyme plays a crucial role in maintaining the proper function of red blood cells, especially in conditions where hemolysis is present.

**FIG. 1.** Inheritance pattern of glucose-6-phosphate dehydrogenase deficiency in Chinese families.

(1) Propositus (NYM and NCK, female/6 days) are twins, showing neonatal jaundice and kernicterus.

(2) Propositus (CWL, male/5 days) shows haemolytic jaundice and haemoglobinuria.

(3) Propositus (HWS, male/neonate) shows haemolytic jaundice exchange transfusion.

(4) Propositus (CM, male/neonate).

(5) Propositus (CYS, male/neonate) Mother had haemolytic jaundice in late pregnancy.

(6) Propositus (LMW, male/8 days) shows haemolytic jaundice.

Activity of G6PD expressed in U.O.D. 340 mg./min./g. haemoglobin.
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G6PD deficiency in Caucasians and in Chinese. However, recent studies of the physicochemical properties of G6PD have shown dissimilarities between the two races in the electrophoretic mobility, thermostability, optimal pH activity curve, Michaelis constant for glucose-6-phosphate, and nicotinamide adenine-dinucleotide-phosphate, and usage of substrate analogues (Wong, Shih, Hsia, and Tsao, 1965; McCurdy, Kirkman, Naiman, Jim, and Pickard, 1966). Consideration of all these facts, together with the modifying effects of the environmental and secondary genetic factors to which these two geographically widely separate races have been exposed in their long history, makes complete identity in all characteristics of G6PD deficiency in Caucasians and Chinese highly unlikely: difference in some of the clinical or biochemical manifestations will doubtless be defined in due course.

Our study shows no difference in the activity of erythrocyte AMPE in normal and G6PD-deficient Chinese. A racial difference may exist in this respect, for Oski et al. (1963) reported that AMPE deficiency was associated with G6PD deficiency in Caucasians. The authors considered this to be a consistent biochemical difference between Caucasian and Negro mutants, but their finding has not been confirmed by other investigators and its value as a criterion for differentiating G6PD deficiency in these two races remains doubtful.

In estimating the gene frequency of G6PD deficiency in the general population, it is customary to choose male subjects for screening tests. This is because the results of screening tests sometimes appear doubtful in heterozygous females, a proportion of whom may escape detection by conventional screening methods. The incidence of deficiency of G6PD in male Chinese populations was reported as 3-74% by Yue and Strickland (1965) and as 5.5% by Chan, Todd, and Wong (1964). The disparity between these figures probably arises because Yue and Strickland studied the deficiency among neonates, whereas Chan and his co-workers studied adult hospital inpatients. The 3.6% incidence of G6PD deficiency in male neonates in our study is very close to that of Yue and Strickland. Our study has also indicated that the incidence does not differ materially between certain parts of Kwangtung Province in which different dialects are spoken.

Our results also show that G6PD deficiency accounts for about 15-4% of cases of neonatal jaundice warranting admission to hospital among Chinese in Hong Kong. Over the past three years in our hospital 55% of the cases of kernicterus have been deficient in the enzyme. Wong (1965) found that nearly 50% of kernicterus among Chinese in Singapore is due to G6PD deficiency. Since the enzyme level in male mutants is usually much lower than that in female mutants, one might postulate that G6PD deficiency is a more important cause of neonatal jaundice in male mutants than in female mutants. In Greece the sex ratio of neonatal jaundice due to G6PD deficiency was reported as three males to one female (Motulsky, 1965). Our findings indicate that this is not true in Chinese, however: the relative importance of the enzyme defect does not differ significantly in male and female jaundiced neonates, and neonatal jaundice occurs in all types of mutants. Thus the haemolytic process in G6PD mutants is not related directly to the level of enzyme activity. Other factors which help to determine the occurrence of the haemolysis must be sought in individual cases with the defect.

We are extremely grateful to Professor J. B. Gibson, and Professor E. C. Field, University of Hong Kong, for their continued help and stimulation in this study. Special thanks are due to Dr. Lopez for his cooperation in providing the specimens for this study and to Dr. J. Grant for his valuable advice. Our sincere appreciation is also due to Miss K. L. Leung and Mr. M. Chan.

REFERENCES