Screening for hyperglycaemia in pregnancy: analysis of two screening protocols and review of current methods

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SUMMARY

We assessed the ability of two screening protocols to detect varying degrees of hyperglycaemia in pregnancy and to compare fetal outcome in those found to have normal and abnormal glucose metabolism by either protocol. 493 pregnant women were identified by one of two screening protocols to be at risk of hyperglycaemia in pregnancy. Pregnancy complications, induction of labour, method of delivery, birth weight, incidence of congenital anomalies and neonatal complications were assessed; there were no significant differences between those with normal and abnormal glucose metabolism detected by either protocol apart from a significant linear trend for the incidence of large for gestational infants with increasing hyperglycaemia in both groups. Protocol B was as effective in detecting new hyperglycaemia in pregnancy as Protocol A. It involved the use of a breakfast meal profile in the initial assessment of those screened positive, reducing the need for glucose tolerance tests in the vast majority of cases. In the population studied, hyperglycaemia in pregnancy was not associated with adverse fetal outcome.

INTRODUCTION

Hyperglycaemia in pregnancy is a term which can be used to encompass a large spectrum of disordered carbohydrate metabolism, which ranges from the upper end of normality to overt clinical diabetes. Pregnancy has important effects on carbohydrate metabolism, exerted mainly through a decrease in insulin sensitivity, which results in higher post prandial blood glucose levels. In pregnant women with a normal pancreatic β cell reserve, insulin secretion is increased in response to this decreased sensitivity, and glucose homeostasis is restored.1 Pregnancy can thus unmask a defect in carbohydrate metabolism in those who have a limited β cell reserve, resulting in hyperglycaemia of varying severity. Even in present day obstetric practice, hyperglycaemia in pregnancy presents a major risk to the fetus, the effects of which extend from fetal life through neonatal life into adolescence. Hyperglycaemia in pregnancy may damage fetal pancreatic β cells, increasing susceptibility to carbohydrate intolerance in the future.2,3

The aim of screening mothers for evidence of abnormal carbohydrate metabolism in pregnancy is to minimise or eliminate these risks to the fetus. There are a number of screening tests in current use, with no consensus view as to the best method. In the UK the methods more commonly used include clinical risk factors, glycosuria, random plasma glucose and glycosylated haemoglobin. Each of these methods when used alone has relatively low sensitivity and specificity. The aim of this study was to look at fetal outcome in pregnancies complicated by varying degrees of hyperglycaemia detected by two screening protocols between 1992 and 1996. Those mothers identified by the two screening protocols to have hyperglycaemia in pregnancy, went on to have

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either a 75 g oral glucose tolerance test (OGTT). (1992-1994) or a 300 kcal breakfast meal test (1994-1996). Fetal outcome in those found to have normal and abnormal carbohydrate metabolism by either test, was analysed, in an attempt to ascertain if either test was a ‘predictor’ for adverse fetal outcome.

PATIENTS AND METHODS

1. Protocol A

Between 1/3/92 and 28/2/94 all patients attending the ante-natal clinic in the Royal Maternity Hospital (RMH) were screened at first booking using ‘clinical risk factors’ and random venous plasma glucose at booking. In addition all patients had urine tested for glucose at each visit. (Table I). Those mothers with one or more clinical risk factors and/or random venous plasma glucose > 6.6 mmol/l and/or the presence of glycosuria > + on two or more occasions; had a 75 g OGTT at around 28 weeks (75 g glucose load, taken orally, after an overnight fast, with venous plasma glucose measured at 0, 30, 60, 90 and 120 minutes). Results were interpreted as shown in Table II.

Those patients found to have impaired glucose tolerance using these criteria went on to have a meal profile. This consisted of ‘breakfast’ and

### Table II

| Venous plasma glucose (mmol/l) | Normal | Impaired G.T. | D.M. |
|-------------------------------|--------|---------------|------|
| Fasting                       | <6.0   | 6.0-7.9       | ≥8   |
| 2 hour                        | <9.0   | 9.0-10.9      | ≥11.0|

‘lunch’ meals, containing 42 g carbohydrate (300 kcal) and 32 g carbohydrate (320 kcal) respectively, with plasma glucose estimated before and two hours after each meal. Results were interpreted as shown in Table III. The meal profile was done in order to assess maternal glycaemic response to normal diet and so determine if treatment was necessary. If a mother had an abnormal meal profile result she was given dietary advice – restricted food intake to 1500-2000 kcal/day, and the meal profile repeated in one week. Only then, if on the diet the result of the meal profile remained abnormal, was insulin treatment considered. If a reading of 11 mmol/l

### Table I

| PROTOCOL A | PROTOCOL B |
|------------|------------|
| **Screening methods:** | **Screening methods:** |
| Clinical risk factors | Random venous plasma glucose |
| (FH diabetes 1st degree relative, previous baby>4.5 kg, previous unexplained stillbirth or neonatal death, previous fetal abnormality, maternal weight >90 kg.) | (RVPG) – Booking visit |
| Random venous plasma glucose (RVGP) – booking visit | – 28 weeks |
| Urine testing for glycosuria | Urine testing for glycosuria |
| **Diagnosis** | **Diagnosis** |
| 75 g oral glucose tolerance test (=28 wks) | 75 g oral glucose tolerance test |
| (If clinical criteria and/or RVPG >6.6 mmol/l and/or glycosuria > + on two or more occasions | (If Breakfast meal test abnormal) |
| (357 patients screened: 357 had a GTT) | (136 patients screened: 3 had a GTT) |
or more was found at any time the patient was diagnosed diabetic and insulin treatment commenced.

In this two year period 378 mothers were identified by the screening protocol to be at risk of hyperglycaemia in pregnancy and had a 75 g OGTT performed; 21 were excluded from further study for various reasons, including multiple pregnancy and vomiting after the glucose load. In total, 357 singleton pregnancies were studied (5.8% of the antenatal population).

### TABLE III

**Interpretation of Breakfast Meal Test**

| 2 hour glucose: | mean = 5.2 mmol/l |
|-----------------|-------------------|
| mean + 2 S.D.   | = 6.8 mmol/l      |
| Arbitrary cut-off| 8 mmol/l          |
| considered abnormal |

(Roberts – study of 102 unselected mothers whom had breakfast meal test – 1992 Belfast)

2. PROTOCOL B

Between 1/3/94 and 28/2/96 the screening protocol was changed, so that mothers were not identified to be at risk of having hyperglycaemia in pregnancy purely because of clinical risk factors (Table I). In addition, a decision was taken to test maternal glycaemic response to the intake of normal foodstuffs, only proceeding to formal glucose tolerance testing if this was deemed to be abnormal. During this two year period, all patients attending the antenatal clinic in RMH were screened using random venous plasma glucose at booking at 28 weeks and at any other time if thought necessary by the obstetrician. All patients had urine tested for glucose at each antenatal visit. Those patients with a random venous plasma glucose > 6.6 mmol/l or the presence of glycosuria on two or more occasions went on to have a breakfast meal test.

The breakfast meal test consisted of a 300 kcal breakfast meal, containing 40 g of carbohydrate – a standard portion of breakfast cereal, two rounds of toast, milk, butter and a cup of tea. It was undertaken after an overnight fast, venous plasma glucose being estimated before and two hours after the meal. Results were interpreted as shown in Table III. For the purpose of comparison with the group of patients found to have IGT by the 75 g OGTT in 1992-94, those patients who had a 2 hr glucose < 8 mmol/l were subdivided into two groups (i) two hr glucose < 6.8 mmol/l and (2) two hr glucose 6.9-7.9 mmol/l. Those patients with abnormal results were given dietary advice (food intake restricted to 1500-2000 kcal/day), and the breakfast meal test repeated in one week. If after one week on the diet the breakfast meal test result was still abnormal, as defined above, a 75 g OGTT was performed. A blood glucose of > 11 mmol/l was regarded as diagnostic of diabetes, and insulin treatment considered. In total, 155 mothers had a breakfast meal test in this two year period, of whom 19 were excluded from further study because of the reasons outlined previously. Therefore, 136 singleton pregnancies identified by the screening protocol in this two year period were studied (2.4% of the antenatal population).

### RESULTS

Of the 357 glucose tolerance tests undertaken, 243 (68%) were carried out purely because of one or more positive clinical criteria, 70 (20%) because of glycosuria, and 35 (10%) because of a raised blood glucose (>6.6 mmol/l). Nine patients had a GTT performed for other reasons, which included ‘large baby’, ‘polyhydramnios’ and ‘obstetrician request’ and a number of patients had more than one indication. Of these mothers 12 were found to have impaired glucose tolerance (IGT) and three to have gestational diabetes. The 12 mothers with IGT had a meal profile, four of which were abnormal. These mothers were given dietary advice and none required insulin treatment. Of the three mothers found to have gestational diabetes two were started on insulin and one was treated with diet only.

In total, 136 patients had a breakfast meal test, of which 106 (78%) were carried out because of a random venous plasma glucose > 6.6 mmol/l, 18 (13%) because of glycosuria and 10 for reasons other than these (mainly ‘obstetrician request’ – because of one or more positive clinical criteria). Of these mothers three were found to have abnormal results. They were all given dietary advice initially. Two mothers had the breakfast meal test repeated; in both cases it was still abnormal and a 75 g OGTT was performed and a diagnosis of diabetes mellitus made. The other patient was admitted to hospital with acute appendicitis before the test could be repeated, and was diagnosed with diabetes while in hospital.

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All three patients with abnormal breakfast meal tests required insulin treatment.

Most patients had glycosylated haemoglobin (HbA₁c) measured at the time of the GTT or breakfast meal test. The methods used for estimating HbA₁c changed twice in the four year period and the results have been adapted accordingly. HbA₁c was significantly higher (p <0.05) in those with IGT (3.8%) compared to normal GTT results (3.2%) and in those with abnormal (4.5%) compared to normal breakfast test results (3.5%).

Pregnancy-induced hypertension, pre-eclampsia, urinary tract infection, and polyhydramnios were the commonest antenatal complications, but none was found to be more common in mothers with an abnormal GTT or breakfast meal test. Labour was induced in 150 (44%) of those with normal GTT results, 5 (42%) of those with IGT, and in one gestational diabetic mother (33%). In those who had the breakfast meal test, 52 (39%) with a normal result, and none of those with an abnormal result, had labour induced.

Most mothers with normal GTT and breakfast meal test results had normal vaginal deliveries. Eight mothers with impaired glucose tolerance had a caesarean section, four being elective (previous caesarean section in three patients, and primary infertility in a 37 year old) and four being emergency caesarean sections. A higher incidence of caesarean section associated with impaired glucose tolerance has been reported before. The caesarean section rates for those with normal GTT and breakfast meal test results are similar to the Royal Maternity Hospital overall caesarean section rates for that period (Table IV).

Fetal outcomes for the two groups are shown in Table V. There was no increase in perinatal mortality or incidence of birth trauma in babies born to mothers with abnormal tests in either group. There were no statistically significant differences in birth weight or gestational age at delivery in babies born to mothers with abnormal tests in either group. There was a significant linear trend (p <0.001) in the incidence of large for gestational age babies with increasing hyperglycaemia in both groups. Most babies with congenital abnormalities, major and minor, in the study group were born to mothers with normal GTT or breakfast meal test results. Mean APGAR scores at one and five minutes were similar in those babies born to mothers with normal and abnormal GTT and breakfast meal test results.

| Glucose Tolerance Test | Breakfast Meal Test |
|------------------------|---------------------|
| Normal | IGT | DM | Normal (<6.8) | Normal (6.9-7.9) | AB-Normal |
| Normal | 342 | 12 | 3 | 123 | 10 | 3 |
| Delivery | 66% | 33% | 33% | 59% | 50% | 67% |
| Instrumental Delivery | 48 | 0 | 1 | 15 | 1 | 0 |
| Caesarean Section (total) | 20% | 67% | 33% | 28% | 40% | 33% |

| Mode of delivery | All | IDDM | All | IDDM |
|------------------|-----|------|-----|------|
| Caesarean Section Rate | 21% | 47% | 24% | 52% |

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The incidence of neonatal complications known be more common in the infant of the diabetic mother was assessed. There was no evidence to suggest that any of these complications were more common in those babies born to mothers with hyperglycaemia in pregnancy. Most babies who required admission to the special care baby unit were born to mothers with normal GTT or breakfast meal test results.

During the four year period studied, only six cases of gestational diabetes were discovered; three by the GTT and three by the breakfast meal test. Five of these patients were treated with insulin, and all stopped insulin post-delivery. They were all seen subsequently at the Royal Victoria Hospital. Clinical records were traced for four of the five patients, all of whom now have Type 1 diabetes and are on insulin treatment.

**DISCUSSION**

The aim of screening mothers for evidence of abnormal carbohydrate metabolism in pregnancy is to detect the problem at an early stage and so prevent any adverse fetal outcome. The only meaningful criteria by which to judge the importance of the state of glucose metabolism in pregnancy are fetal outcome, either in the short or longer term, or the long term maternal outcome. Various indices of fetal outcome have been used to assess the effect of hyperglycaemia in pregnancy. Because of the general decline in perinatal mortality rates in recent years, this index of fetal outcome can no longer be used as a practical outcome measure. Therefore other short term pregnancy outcomes have become more important in assessing the effect, if any, of maternal hyperglycaemia. Maternal hyperglycaemia through its effect on fetal cells, can cause accelerated fetal growth. The fetal β cells are stimulated to produce insulin, an anabolic hormone which causes visceral enlargement and excess fat deposition, resulting in the macrosomic infant. Higher rates of birth trauma and operative delivery are seen in these pregnancies, with resulting effects on maternal and neonatal morbidity.

Fetal hyperinsulinaemia may also inhibit the pulmonary maturation processes necessary for surfactant production, and so contribute to the increased incidence of respiratory distress syndrome seen in infants of diabetic mothers. The enhanced responsiveness of the fetal β cell may extend into neonatal life and contribute to the development of neonatal hypoglycaemia. Other indices of neonatal morbidity have been used as outcome measures. Maresh found that

**TABLE V**

|                        | Glucose Tolerance Test | Breakfast Meal Test |
|------------------------|------------------------|---------------------|
|                        | Normal (<9.0)          | IGT (9.0-10.9)      | DM (>11) | Normal (<6.8) | Normal (6.8-7.9) | Abnormal (>8.0) |
| No. of Patients        | 342                    | 12                  | 3        | 123           | 10              | 3              |
| Mean Birth Weight (kg) | 3.54                   | 3.79                | 3.26     | 3.46          | 4.04            | 3.25           |
| Mean Gestational Age (weeks) | 39.1             | 38.1                | 37.3     | 39.0          | 39.1            | 36.7           |
| Large for Gestational Age | 72(21%)          | 6(50%)              | 1(33%)   | 22(17%)       | 4(40%)          | 2(67%)         |
| Minor Congenital Abnormality | 44(13%)     | 1(8%)               | 1(33%)   | 7(6%)         | 1(10%)          | 0(0%)          |
| Major Congenital Abnormality | 5(1%)        | 0(0%)               | 0(0%)    | 4(3%)         | 0(0%)           | 0(0%)          |

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hypoglycaemia and polycythaemia, or admission to a special care baby unit was significantly related to the severity of gestational diabetes but not with maternal age or obesity. He also found that birth weight was more related to maternal obesity than to age or to severity of the gestational diabetes.

There are relatively few studies of fetal outcome in mothers with lesser degrees of hyperglycaemia in pregnancy. Talligaro\textsuperscript{12} found an association with adverse fetal outcome – macrosomia, congenital abnormality, and delivery by caesarean section in mothers with milder degrees of hyperglycaemia in pregnancy. The Toronto tri-hospital study found a graded increase in adverse materno-fetal outcomes associated with increasing carbohydrate intolerance in women without gestational diabetes.\textsuperscript{4} Roberts\textsuperscript{6} did not find any adverse fetal outcome or neonatal morbidity, but he was able to demonstrate a significantly higher caesarean section rate for mothers with impaired glucose tolerance.

There is well established evidence that gestational diabetes increases the subsequent risk of developing diabetes mellitus.\textsuperscript{2,3,13} The third International Workshop Conference on gestational diabetes\textsuperscript{2} recommended that these women should be educated regarding symptoms of overt diabetes, and be followed up at regular intervals. There is evidence that the offspring of women with gestational diabetes have an increased risk of obesity in adolescence and of developing glucose intolerance in the future.\textsuperscript{2} Identification and treatment of hyperglycaemia in pregnancy may thus have far reaching implications for the next generation.

There is no doubt that identification and treatment of mothers with frank diabetes in pregnancy is of benefit to mother and fetus. What is less certain is the benefit of identifying lesser degrees of hyperglycaemia, and screening for hyperglycaemia is the subject of much controversy. There is no consensus about who to screen, when to screen, which screening test to use, which diagnostic test to use, and how to interpret the results. The resulting effect is widespread variation in practice between different units, highlighted in two recent reports. Nelson-Piercy\textsuperscript{14} looked at practices in one Regional Health Authority in London, and Jardine Brown\textsuperscript{15} analysed a nationwide survey on screening for gestational diabetes. This latter report, compiled by the Pregnancy and Neonatal Care group, reveals that most units in the United Kingdom use routine testing for glycosuria and clinical risk factors as the basis for screening, with only a minority using routine blood glucose testing. The 75 g OGTT is the most widely used diagnostic test, being undertaken in many units solely because of positive clinical risk factors.

The aim of screening for a condition is to detect it at a stage where treatment will improve outcome. The screening test should be sensitive, specific, acceptable, and the treatment must be effective.\textsuperscript{16} Jarrett\textsuperscript{17} has argued that screening for gestational diabetes does not fulfil the criteria for a screening test; it does not have an agreed definition, and there is no consensus about management. He did however acknowledge the value of screening in predicting future risk of non insulin dependent diabetes for the mother, but found few, if any, benefits to the fetus. Carpenter\textsuperscript{18} suggested that identification of pregnant women with previously unknown defects in carbohydrate metabolism 'may be justified as a screening measure for later diabetes, since women so identified may benefit from later medical follow-up'. He also referred to fetal benefits of diagnosis and treatment of hyperglycaemia in pregnancy in terms of reduced perinatal mortality and morbidity.

There are a number of screening tests in current use, with no consensus view as to the best method. Overall, the highest sensitivity and specificity for the outcome of a 100 g GTT is found with the 50 g oral glucose challenge test,\textsuperscript{19} recommended by the American Diabetes Association.\textsuperscript{20} In the UK, this method has not found favour,\textsuperscript{19} and the methods used more commonly include:

(i) Clinical risk factors (potential diabetic features) such as glycosuria, previous infant >4.5 kg, previous stillbirth, neonatal death or congenital abnormality and maternal obesity. The use of these clinical risk factors alone has low sensitivity and specificity, 50% and 66% respectively in one review,\textsuperscript{21} and 50 and 50% in another.\textsuperscript{19} Coustan suggested that the taking of a history can be used as a screening test, and that the sensitivity can be increased by combining it with maternal age (>25 years) and obesity (pre-pregnancy weight >150 pounds), but screening by this method is thought to be relatively inefficient. Gillmer\textsuperscript{22} in his review of diabetes in pregnancy found that at least 30% of patients with gestational diabetes do not have such features in their history.
(ii) Glycosuria: Sutherland reported a prevalence of glycosuria in pregnant women of 11.3%, and found that glycosuria in a second fasting sample (not random glycosuria), was associated with an increased risk of gestational diabetes (15%). Pettitt showed that random glycosuria in the third trimester was more common with increasing hyperglycaemia. However, a substantial number of women with hyperglycaemia in pregnancy will not have glycosuria, and as a screening method it is of low sensitivity.

(iii) Random blood sugar has been evaluated as a method of screening by various investigators. Jowett and Nasratt agreed that this method used alone was not an efficient screening test. O'Sullivan however found that a random blood glucose, when combined with maternal age >25 years as a screening test, had a sensitivity of 88% and specificity of 82%. Maresht in his review of glucose intolerance in pregnancy reported higher sensitivities when random blood glucose was combined with potential diabetic features as a screening test.

(iv) Glycosylated haemoglobin (HbA\textsubscript{lc}) HbA\textsubscript{lc} is a useful indicator of blood glucose levels over the preceding 4-12 weeks. In diabetic pregnancy, high levels of HbA\textsubscript{lc} have been shown to be associated with an increased risk of congenital malformation and perinatal death. Although HbA\textsubscript{lc} is used by some units as a screening test for hyperglycaemia in pregnancy its value has been questioned. It has been found to be of low sensitivity and specificity in one study even though mean HbA\textsubscript{lc} levels were raised in patients with carbohydrate intolerance diagnosed by a 3 hr 100 g OGTT. In another study HbA\textsubscript{lc} was found to have a poor predictive value for pregnancy outcome. (Personal Communication) Lind recommended that all units use random blood glucose as a basis for screening, and the 75 g OGTT for diagnosis, interpreted by WHO criteria, for the sake of international uniformity in the diagnosis of hyperglycaemia in pregnancy.

There is no consensus view as to the best method of screening for hyperglycaemia in pregnancy. In the absence of an agreed standard, Jardine Brown in the report of the pregnancy and neonatal care group has suggested a screening protocol. This involves urine testing for glycosuria at every antenatal visit, timed random glucose measurements at booking, 28 weeks and if there is > + glycosuria. The report recommends that a 75 g oral GTT is performed, followed by a meal profile if the GTT is abnormal, before deciding on treatment.

Gestational diabetes, as defined by the WHO is diagnosed using a 75 g oral glucose tolerance test (OGTT) with blood glucose estimations at 0, 30, 60, 90 and 120 minutes, and defined cut-off points for diagnosis at 0 and 120 minutes. It now includes a category of “impaired gestational glucose tolerance” (IGT), an intermediate category between normality and gestational diabetes. In North America the 100 g OGTT is more commonly used for diagnosis of gestational diabetes, defined by the American Diabetes Association, using cut-off points at 0, 1, 2 and 3 hours (NDDG criteria). A 50 g OGTT is used by the Americans as a screening test to identify those mothers requiring a 100 g OGTT, but is used by some as the diagnostic test.

The OGTT has traditionally been used to diagnose gestational diabetes. It uses an unphysiological glucose load which may be unpalatable to pregnant women. The results do not reflect the levels of blood glucose to which the fetus is normally exposed. It seems more logical, therefore, to study maternal glycaemic responses to the intake of normal foodstuffs, since it is hyperglycaemia in relation to normal diet that is likely to be associated with adverse fetal outcome. Indeed, many centres measure blood glucose before and after a normal “standardised meal, in mothers with an abnormal GTT result, before considering the need for treatment. We felt that it would be more logical to identify abnormal meal profile responses as the primary diagnostic process. A number of studies have looked at maternal glucose responses to more physiological “meals”. Sutherland and colleagues in Aberdeen found that glucose response to a standardised breakfast test meal correlated more closely with percentile birth weight than the 75 g OGTT. Cheney and colleagues showed different insulin and glucose responses to a breakfast tolerance test in lean and obese women with gestational diabetes.

They concluded that a simple breakfast meal test was useful in assessing pregnant women with gestational diabetes, and that it was more physiological than glucose loading. Roberts compared the 75 g OGTT and a simple 300 kcal breakfast meal test for their ability to predict fetal outcome. He found that in the Belfast population,
neither test was a useful indicator of pregnancy outcome in mothers not already known to be diabetic, and that there was no benefit in continuing the test into the pre and post lunch period. Whether or not the breakfast test will be of any value in predicting the risk of future diabetes in the mother remains to be seen.

In conclusion, the breakfast meal test is as effective in detecting hyperglycaemia in pregnancy as the traditional 75 g OGTT. It is a more physiological test of glucose metabolism in pregnancy and is likely to be more acceptable to patients. We did not find any evidence of adverse fetal outcome associated with hyperglycaemia in pregnancy, but did find that there was a high incidence of subsequent Type 1 diabetes in those mothers found to have gestational diabetes. The forthcoming HAPO (Hyperglycaemia and Adverse Pregnancy Outcome) study aims to identify in a much larger population, made up of various ethnic groups in different countries, whether lesser degrees of hyperglycaemia in pregnancy are associated with increased risk of adverse maternal, fetal or neonatal outcome.

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