# Screening for Gestational Diabetes in a High-Risk Population

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*One hundred eighty-one pregnant Navajo women were screened for gestational diabetes. The 50-g oral glucose screening test was greater than 7.2 mmol/L (130 mg/dL) in 44 of 181 subjects (24.3 percent) and greater than 8.3 mmol/L (150 mg/dL) in 23 of 181 subjects (12.7 percent). The incidence of gestational diabetes in the study population was 6.1 percent of all pregnancies by standard oral glucose tolerance testing. Incidence of gestational diabetes was 9.5 percent in 21 subjects whose screening test was 7.2 to 8.3 mmol/L (130 to 149 mg/dL) and 39.1 percent in 23 subjects whose screening test was 8.3 mmol/L (150 mg/dL) or greater.*

*Using equal to or greater than 7.2 mmol/L (130 mg/dL) of glucose as the definition of an abnormal screening test yielded a 0.80 specificity and a 0.25 positive predictive value, while the cost for each case of gestational diabetes detected was $114. Using equal to or greater than 8.3 mmol/L (150 mg/dL) of glucose as the definition of an abnormal screening test yielded a 0.81 sensitivity, 0.58 specificity, and 0.39 positive predictive value, while the cost for each case of gestational diabetes detected was $106.*

*Logistic regression analyses demonstrated that the screening test was more strongly associated with the diagnoses of gestational diabetes than any other risk factor for gestational diabetes. Universal screening of gestational diabetes is recommended in this high-risk population using equal to or greater than 7.2 mmol/L (130 mg/dL) of glucose as the definition of an abnormal screening test.*

Gestational diabetes mellitus is a condition in which the patient manifests glucose intolerance during pregnancy.[1,2] The exact pathophysiology and diagnostic criteria for this disorder are a matter of some controversy, but most estimates of the incidence of gestational diabetes in the black and white populations range from 1 to 3 percent of all pregnancies.[3] Furthermore, the hyperglycemic state of gestational diabetes has convincingly been shown to be associated with increased fetal and neonatal morbidity and with a propensity of the gestational diabetic mothers to go on to develop diabetes mellitus later in life.[4]

The increased fetal and neonatal morbidity of gestational diabetes is characterized by macrosomia, increased traumatic and operative delivery, increased prematurity and respiratory distress syndrome, and metabolic derangements including hypoglycemia, hypocalcemia, hyperbilirubinemia, and polycythemia. Congenital anomaly rates are not increased in gestational diabetes, but are elevated in more severe forms of diabetes in pregnancy. Mortality may be somewhat increased in gestational diabetes, but reports disagree on this point.[1,2,5] Among mothers with gestational diabetes, about 60 percent go on to develop overt diabetes within 16 years after delivery.[6]

Because of the significant morbidity associated with this condition, the availability of reasonably reliable screening tests, the relatively high incidence, the asymptomatic nature of the condition, and the effectiveness of treatment, screening for gestational diabetes seems well justified.[7] Nevertheless, debate rages over whether all pregnant

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women[8,9] or only those over the age of 25 years should be screened,[10,11] and there is disagreement as to what screening test should be used, and at what point the screening test result is considered to be abnormal.[12–16]

The most commonly used screening test for gestational diabetes in the United States is a modification of the method of O'Sullivan et al, in which a 50-g oral glucose ingestion is followed in one hour by a single plasma glucose determination.[17] Abnormally elevated glucose screening tests are followed by administration of a three-hour, 100-g oral glucose tolerance test to confirm or exclude "definitively" the diagnosis of gestational diabetes.[18]

Unfortunately there is little agreement as to which screening glucose value ought to be considered elevated in the glucose screening test. Recommendations range from 7.2 mmol/L (130 mg/dL)[10] to 8.9 mmol/L (160 mg/dL), and the distribution of screening test results in different population groups has been incompletely described, with resultant confusion on the part of clinicians and researchers.[3,12,19]

In this study the universal use of the glucose screening test was evaluated in a well-defined primary care population at high risk for gestational diabetes. Logistic regression analysis is applied to evaluate the relative risk of gestational diabetes based on (1) subjects' glucose screening test results, and (2) classic historical risk factors for gestational diabetes. The data also allow calculation of the sensitivity and specificity of the screening test at different threshold definitions of abnormal results. Thus the clinical usefulness of the screening test is precisely defined and its optimal use described in the study population.

## METHODS

### Study Population and Selection Criteria

Of the 493 deliveries at Tuba City and Chinle Indian Health Service hospitals between April 1 and July 23, 1985, 283 of the mothers received prenatal care before 32 weeks' gestation at one of the two hospitals and, thus, were eligible for the study. Most of the other mothers received prenatal care at other Indian Health Service facilities. Excluded from the study were 30 patients who did not belong to the Navajo tribe, 37 patients who did not receive a screening test before 32 weeks' gestation, and 11 patients whose charts could not be found. One patient had insulin-dependent diabetes mellitus before pregnancy and was excluded. Finally, 23 patients received special analysis, 21 because they were screened earlier than the protocol-dictated 28 weeks of gestation and 2 because, although they had abnormal screening results, a three-hour oral glucose test was not performed. This left 181 eligible study subjects who were included in the study.

### Screening Procedure

A 50-g glucose load (Glucola, Miles Laboratories) was administered to the nonfasting patient during routine prenatal care between 28 and 32 weeks of gestation, and plasma glucose levels were determined one hour later. Those patients who had a plasma glucose level of 7.2 mmol/L (130 mg/dL) or greater were asked to return for a three-hour oral glucose tolerance test to confirm the diagnosis of gestational diabetes. The diagnosis of gestational diabetes was established when two fasting plasma glucose levels were greater than 5.8 mmol/L (105 mg/dL), or when plasma glucose levels after a standard 100-g glucose load met two of the following three conditions: (1) 10.5 mmol/L (190 mg/dL) or greater at one hour, (2) 9.2 mmol/L (165 mg/dL) or greater at two hours, or (3) 8.0 mmol/L (145 mg/dL) or greater at three hours. Subjects with a screening value less than 7.2 mmol/L (130 mg/dL) were not given glucose tolerance tests. Blood for plasma glucose measurements was collected by antecubital venipuncture in Vacutainers containing sodium fluoride and processed the same day on automated clinical chemistry machines.

### Data Collection

Data collected on study subjects included date of birth, tribe, number of previous pregnancies, prepregnant weight, or a history of the following: gestational diabetes, stillbirth (greater than 20 weeks' gestation), prior macrosomic baby (greater than 4,000 g), chronic hypertension requiring drug therapy, gestational hypertension (diastolic greater than 90 mmHg on two occasions or a 30 mmHg rise from prepregnant levels), hydramnios, prior child with congenital malformation, or a family history of diabetes mellitus.

For each pregnancy data collected included date of last menstrual period, estimated date of confinement, glycosuria (greater than 2+ on urine dipsticks, Ames Co) on two or more occasions before the glucose screening test, dates and results of all ultrasound examinations, and dates and results of all glucose screening tests, glucose tolerance tests, and fetal activity tests. Type of delivery was recorded as spontaneous vaginal delivery, forceps or suction-assisted vaginal delivery, or cesarean section.

Infant characteristics recorded were birthweight, size for gestational age, Apgar scores at 1 and 5 minutes, age by Dubowitz rating, presence of meconium staining of fluid or membranes, neonatal hypoglycemia (blood glucose levels less than 2.2 mmol/L [40 mg/dL]), neonatal hyperbilirubinemia greater than 205 μmol/L (12 mg/dL) in-hospital stay, and fetal monitor strip results (normal or abnormal).

## ANALYSIS

A least squares multiple regression model[20] was used to assess the relationship of potential risk factors (maternal age, prepregnancy weight, family history of diabetes, parity, history of gestational diabetes, history of macrosomia, and gestational age at which the glucose screening test was administered) and the glucose screening test result (recorded as milligrams per deciliter). Regression analysis was done on the total sample (n = 177) after the deletion of five respondents with missing data on one or more of the independent variables. The screening glucose test was then recorded as either positive or negative, and the logistic multiple regression model was used to determine the association of independent risk factors with a routine screening test.

To test the relationship between independent risk factors and a positive glucose tolerance test (a diagnosis of gestational diabetes), a logistic multiple regression model[21] was used on (1) the total sample (n = 177), (2) the subsample with a glucose screening test result of 7.2 mmol/L (130 mg/dL) or greater (n = 44), (3) the subsample of primiparous subjects (n = 64), (4) the subsample of multiparous subjects (n = 117), (5) the subsample of subjects aged less than 25 years (n = 99), and (6) the subsample of subjects aged 25 years and over (n = 81).

All data were analyzed using SAS (Statistical Analysis System) on an IBM mainframe computer at the University of Connecticut. Standard epidemiologic techniques described by Galen and Gambino[22] were used to define the sensitivity and specificity of the screening test at various definitions of abnormal results.

## RESULTS

Of 181 eligible subjects, 44 (24.3 percent) had a screening blood glucose level of greater than 7.2 mmol/L (130 mg/dL). Of these, 11 (25 percent) were subsequently classified as having gestational diabetes by the three-hour oral glucose tolerance test. The screening yield for gestational diabetes was two of 21 women (9.5 percent) with screening glucose levels of 7.2 to 8.3 mmol/L (130 to 149 mg/dL) and 9 of 23 women (39.1 percent) with screening glucose levels of 8.3 mmol/L (150 mg/dL) or greater (chi-square = 5.4, 1 *df*, $P < .02$). Overall, 6.1 percent of the 181 patients were classified as having gestational diabetes.

Twenty-one additional patients were screened too early (less than 28 weeks' gestation) for inclusion in the main study, and their results were analyzed separately. Of the 21 patients who were screened before 28 weeks, 5 had an abnormal screening value (24 percent); all 5 had normal glucose tolerance tests. Although this group of patients appeared comparable to the group of 181 patients who were screened between 28 and 32 weeks' gestation, they are excluded from all other analyses in this report because their screening test was not done between 28 and 32 weeks of gestation.

Frequencies of gestational diabetes risk factors by screening test results are displayed in Table 1, in which risk factors that subjects with confirmed gestational diabetes had before definitive testing are tabulated. The women with gestational diabetes were older and weighed more, and they were more likely to have a history of gestational diabetes. There were no statistically significant differences between the group with "false-positive" glucose screening test results and the group that had normal glucose values in any of the variables measured.

Logistic regression analyses were used to assess which factors are associated with risk of gestational diabetes among study subjects. In a model that includes historical risk factors and the glucose screening test result, only the glucose screening test result was associated with risk of gestational diabetes (chi-square = 12.53, P = .0004, R = .36). Only when the glucose screening test was excluded from the logistic regression model did other variables appear to be associated with risk of gestational diabetes. When glucose screening test results were not considered, then risk of gestational diabetes was associated with mother's age (chi-square = 6.94, P = .0084, R = .25) and with history of gestational diabetes (chi-square = 4.07, P = .044, R = .158). More parsimonious models that included fewer variables did not alter these results.*

Logistic regression analysis of the subsample of 81 subjects aged 25 years or older showed that only a screening test result of greater than 8.3 mmol/L (150 mg/dL) was associated with risk of gestational diabetes in this age group. In subjects aged less than 25 years, no variables were significantly associated with risk of gestational diabetes, not even the screening test result. This subgroup included only two subjects (18 percent of known cases) with gestational diabetes, which weakens the statistical power of the analysis.

The logistic regression analysis was then repeated using data from the 44 study subjects whose glucose screening test results were equal to or greater than 7.2 mmol/L (130 mg/dL). Again, only a positive glucose screening test result (defined as equal to or greater than 8.3 mmol/L (150 mg/dL) was predictive of risk of gestational diabetes (chi-square = 4.01, P = .045, R = .20). The same results were observed in similar analyses stratifying by parity for both the 117 multiparous and 64 primiparous subjects. In the logistic regression analysis, the number of subjects who met the study criteria for glycosuria, history of stillbirth,

* *Complete logistic regression results available from author on request.*

**TABLE 1. DISTRIBUTION OF RISK FACTORS FOR GESTATIONAL DIABETES SHOWN FOR THREE GROUPS OF SUBJECTS DEFINED BY SCREENING TEST RESULTS AND BY GLUCOSE TOLERANCE TEST (GTT) RESULTS**

| Risk Factor | Screening Test Results: <7.2 mmol/L (<130 mg/dL) No GTT Done Percent | >7.2 mmol/L (>130 mg/dL) GTT Normal Percent | >7.2 mmol/L (>130 mg/dL) GTT Abnormal Percent |
|---|---|---|---|
| 1. Age >25 yr | 37 | 64 | 82 |
| 2. Weight >130 lb | 46 | 58 | 64 |
| 3. Multiparous | 62 | 67 | 82 |
| 4. Family history of diabetes | 17.8 | 24.2 | 27.3 |
| 5. History of gestational diabetes | 0.7 | 3 | 18.2 |
| 6. History of macrosomia | 5.9 | 12.1 | 18.2 |
| 7. Glycosuria (definition in text) | 0 | 3 | 0 |
| Subjects with 0 of above 7 risk factors | 33.8 | 27.3 | 9.1 |
| Subjects with 1 of above 7 risk factors | 35.3 | 12.1 | 18.2 |
| Subjects with 2 of above 7 risk factors | 21.3 | 36.4 | 36.4 |
| Subjects with 3 or more of above 7 risk factors | 9.6 | 24.3 | 36.4 |
| Total | 100 | 100 | 100 |
| Mean age (yr) | 24.8 | 27.2 | 30.3 |
| Mean weight (lb) | 131 | 135 | 146 |
| Mean parity | 1.4 | 1.9 | 2.2 |

and history of fetal anomaly were so small that these variables could not be evaluated because their statistical distributions violated the assumptions of the model.

In logistic regression analysis using all risk factors as independent variables, only age (chi-square = 9.02, P = .0027, R = 23) and parity (chi-square = 4.04, P = .044, R = −.12) were associated with risk of screening test result of equal to or greater than 8.3 mmol/L (150 mg/dL).

Among 181 women in the study, several historical risk factors were shown to be associated with glucose screening test results by least squares multiple regression analysis (Table 2). The variables that were significantly associated with the test result were mother's age, history of gestational diabetes, and mother's prepregnancy weight. Variables not associated with the test result were family history of diabetes, parity, history of macrosomia, or gestational age at time the test was obtained. So few subjects had glycosuria (more than 2+) on two or more occasions before the glucose screening test was obtained that these data failed to meet distributional assumptions for inclusion in the linear regression model.

The least squares multiple regression model with the above variables included explained 15 percent of the variance in glucose screening test results. More parsimonious models yielded the same conclusion: only age, weight, and history of gestational diabetes were associated with screening test results, and the amount of variance in the test results explained by the models was low. When the subjects were stratified by parity, only mother's age was associated with the screening test result among the 64 primiparous subjects. Among the 117 multiparous subjects, mother's age, prepregnancy weight, and history of gestational diabetes were associated with screening test results.

There were 44 study subjects whose glucose screening test results were equal to or greater than 7.2 mmol/L (130 mg/dL); all of these subjects had a glucose tolerance test done. When 8.3 mmol/L (150 mg/dL) of glucose is selected as the threshold for an abnormal glucose screening test, the sensitivity of this test for detecting gestational diabetes is 9 of 11 cases, or 0.81 (Table 3). The specificity of the test is 0.58, and the positive predictive value is 0.39. Depending on how many cases of gestational diabetes may have been undiagnosed in the 137 subjects whose screening test was less 7.2 mmol/L (130 mg/dL) and who had no glucose tolerance test, the specificity of the test could be as high as 0.92 if analyzed with the entire group of screened subjects included.

Using similar assumptions and a threshold of 7.2 mmol/L (13 mg/dL) for the glucose screening test, the sensitivity of the test would approach 1.0 while the specificity would be 0.80 and the positive predictive value 0.25.

## DISCUSSION

In this study 6.1 percent of pregnant Navajo women were identified as having gestational diabetes. This estimate of

**TABLE 2. MULTIVARIATE LINEAR REGRESSION ANALYSIS SHOWING ASSOCIATION OF INDEPENDENT VARIABLES WITH GLUCOSE SCREENING TEST (SGT) RESULTS (n = 181)**

| | Dependent Variable Screening Glucose Test Results | | | |
|---|---|---|---|---|
| Independent Variables | Degrees of Freedom | Sum of Squares | F Value | P Value |
| Mother's age | 1 | 10841. | 14.55 | .0002 |
| Prepregnancy weight | 1 | 3526. | 4.73 | .0310 |
| Family history of diabetes | 1 | 142. | 0.19 | .6626 |
| Parity | 1 | 588. | 0.79 | .3745 |
| History of gestational diabetes | 1 | 6213. | 8.34 | .0044 |
| Time SGT administered | 1 | 158. | 0.21 | .6448 |
| History of macrosomia | 1 | 1130. | 1.52 | .2197 |

*Model R-square = .15*

incidence is likely to be conservative because it is possible that a small number of additional cases may have gone undiagnosed in subjects whose screening glucose test values were equal to or less than 7.2 mmol/L (130 mg/dL). The observation that 39.1 percent of women with a screening test result of 8.3 mmol/L (150 mg/dL) had gestational diabetes, while only 9.5 percent of women with screening test results between 7.2 and 8.3 mmol/L (130 and 149 mg/dL) had gestational diabetes, however, supports the assumption that very few, if any, cases of gestational diabetes would have been diagnosed among women whose screening test result was less than 7.2 mmol/L (130 mg/dL).

The observed incidence of gestational diabetes of 6.1 percent in Navajo women is substantially higher than the 1 to 3 percent incidence of gestational diabetes in other US black and white populations that have been studied.[3] The factors that contribute to the observed high incidence in Navajos deserve careful study. Of interest is the recent documentation by Hickey et al[23] of a prevalence of diabetes in Navajo adults that is approximately 25 percent in subjects aged over 30 years. Also of interest is the clinical observation that nearly all diabetic Navajos have non–insulin-dependent diabetes.[24,25] Further studies of gestational diabetes among Navajos may be helpful in understanding the contribution of genetic factors and environmental factors in the etiology of gestational diabetes. It is possible that selection bias in determining eligibility of patients for this study may have skewed the estimates of incidence of gestational diabetes, but the data do not permit accurate assessment of this possibility.

A number of maternal and infant characteristics were associated with gestational diabetes in bivariate analysis (Table 1). None of these risk factors, however, was as closely associated with risk of gestational diabetes as was the glucose screening test result. Attempts to do selective glucose screening based on the presence of two or more risk factors for gestational diabetes, such as those shown in Table 1, would have failed to identify 27.3 percent of the cases of gestational diabetes among the study subjects while mandating screening of 38 percent of all patients.

Although this screening strategy may appear attractive to providers who are extremely cost conscious, the lower sensitivity of this strategy is a drawback. Using the criteria of screening only those subjects with two or more of the following risk factors—age greater than 25 years, weight greater than 130 lb, parity greater than 0, family history of diabetes, glycosuria greater than 2+ on two occasions, history of infant birthweight greater than 4,000 g, personal history of gestational diabetes—would have led to 71 of

**TABLE 3. TWO-BY-TWO TABLE SHOWING SENSITIVITY OF GLUCOSE SCREENING TEST (SGT) FOR GESTATIONAL DIABETES AS MEASURED BY ROUTINE GLUCOSE TOLERANCE TEST. TABLE ASSUMES NO ABNORMAL GLUCOSE TOLERANCE TESTS AMONG SUBJECTS WHOSE GLUCOSE SCREENING TEST WAS LESS THAN 7.2 mmol/L (130 mg/dL)**

| | Glucose Screening Test | | |
|---|---|---|---|
| | 8.3 mmol/L (150 mg/dL) | ≥8.3 mmol/L (150 mg/dL) | |
| Glucose tolerance test | | | |
| Normal | 155 | 14 | 169 |
| Abnormal | 2 | 9 | 11 |
| | 157 | 23 | 180 |

*Sensitivity = 9/11 = .81*
*Specificity = 155/169 = .92*
*Positive predictive value = 9/23 = .39*

181 subjects being screened. Of these, 28 would have had a screening test result equal to or greater than 7.2 mmol/L (130 mg/dL) and would have had glucose tolerance tests yielding a diagnosis of gestational diabetes in 8 of the 11 women who have the condition. The cost for each case found (see figures below) is $89, while the sensitivity is 0.73.

Swinker[10] conducted a similar study in a West Virginia family practice on 50 patients and found that 32 percent of the patients had plasma glucose screening results equal to or greater than 7.2 mmol/L (130 mg/dL), compared with 24.3 percent in this study. The incidence estimates of gestational diabetes and positive predictive value of the screening tests of Swinker cannot be compared with those from this study, however, because Swinker used glucose tolerance test criteria that were substantially more lenient than those used here, and her estimated incidence of gestational diabetes may have been elevated. In general, older studies are difficult to evaluate because of the shift in glucose tolerance test definition over the years.[3,12,18,24]

Assuming the marginal cost of the glucose screening test to be $3.50 and the cost of the three-hour glucose tolerance test to be $14 (figures obtained in 1987 from the Tuba City Hospital laboratory), the marginal cost for each case of gestational diabetes detected is $114 using the universal screening with the 7.2 mmol/L (130 mg/dL) screening test cutoff point (181 screening tests and 44 glucose tolerance tests to detect 11 cases of gestational diabetes). Using universal screening with a threshold of 8.2 mmol/L (150 mg/dL) decreases the sensitivity of the screening test to 0.81 while increasing its specificity. Using the screening test in this way, the marginal cost for each case of gestational diabetes detected is $106 (181 screening tests, and 23 glucose tolerance tests, to detect 9 cases of gestational diabetes).

Whether the marginal costs mentioned above are cost effective cannot be determined because the medical, economic, and social "costs" of undetected cases of gestational diabetes are poorly defined and because the marginal cost of screening may vary from place to place. In gestational diabetes the decision as to which method of glucose screening test is most effective normally rests with clinicians, administrators, and patients. In this study population, however, the small differences in cost for each case of gestational diabetes detected and the increased sensitivity of the universal screening test using the 7.2-mmol/L (130-mg/dL) threshold level would suggest that this method is preferable to either universal screening using the 8.2-mmol/L (150-mg/dL) level or to selective screening using risk factors to determine who is screened.

In Hartford, Connecticut, in 1987 the cost of a glucose screening test was $18 and the cost of a three-hour oral glucose tolerance test was $42. When the tests cost this much, the cost for each case of gestational diabetes detected jumps to approximately $300 to $400 depending on the screening criteria applied (selective screening with lower sensitivity and costs, universal screening with higher sensitivity and costs). The dramatic cost differential between the health maintenance organization-like "marginal-cost" approach in the Indian Health Service and the fee-for-service "direct-cost" approach in Hartford's private sector illustrates that economic and political factors may be stronger determinants of screening practices than are epidemiologic or medical considerations. Perhaps strategies that seek to reduce the cost of screening techniques should be a high priority for primary care researchers,[26] medical care administrators, and politicians alike.

The results of this study confirm that the screening test proposed by O'Sullivan et al reliably detects gestational diabetes. This finding supports the observation of a number of other studies,[2,9–11,15] but lends the weight of a more sophisticated multivariate analysis to the conclusions. The glucose screening test was most closely associated with risk of gestational diabetes than were historical risk factors or other antenatal obstetric data, and universal screening with the use of a 7.2-mmol/L (130-mg/dL) level as a criterion for doing a glucose tolerance test increases the sensitivity of the screening test without a prohibitive increase in cost for each case of gestational diabetes detected.

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# Commentary

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The authors have provided valuable information in a difficult area of obstetric care. This report also provides the opportunity to review selected aspects of screening tests and to discuss the use of multivariate analysis techniques.

In assessing the utility of a screening test, one needs to know the sensitivity and specificity of the test and the prevalence of the disease in the population under study. In cost-effectiveness analysis, one also needs to know the direct cost of screening, the costs of diagnostic and therapeutic measures generated by screening, and similar costs for not screening.

In their discussion of screening glucose tolerance tests (SGT), the authors appropriately chose universal screening of their population as the best strategy based upon screening costs. The 6.1 percent reported prevalence of gestational diabetes mellitus is higher than the average 1 to 3 percent reported for the population, and this difference may have significant impact on the cost analysis. Using a prevalence of 3 percent for gestational diabetes, the Hartford costs, the potential sensitivity of 100 percent, and the 80.6 percent specificity of the 7.2 mmol/L (130 mg/dL) cutoff, the cost per case detected increases to $905. Using a history of two or more risk factors as an indication for SGT testing, and assuming the same distribution of risk factors in the populations screened, the cost would be $486 per case detected, missing 8 cases for every 1,000 pregnancies. Compared with universal screening, such a screening program would save $10,704 for every 1,000 pregnancies, or $2,056 for each missed case.

The sensitivity of this screening protocol could be increased, albeit at the cost of decreasing specificity, by screening every woman with one risk factor or more. Using the data of Massion et al from Table 1, the sensitivity of requiring only one risk factor is 91 percent with a specificity of 88 percent. A program based upon one risk factor would cost $654 for every case detected, miss three cases for every 1,000 pregnancies, and save $3,168 for each case missed.

Thus generalizing the results from one population may not be appropriate; even after including the cost of missing three to eight cases vs missing none, a prescreening strategy may be cost effective when considering the prevalence and screening costs in a different population.

Multivariate techniques consider the effects of several factors on an outcome variable. When the outcome variable is continuous, multiple linear regression is the appropriate technique, as used in this study to assess the determinants of SGT results. The model containing variables significantly associated with SGT results explained only 15 percent of the total variation in SGT levels and hence was not clinically useful. An analysis considering a combination of factors associated with an SGT result of greater than 7.2 mmol/L (130 mg/dL) would be clinically significant, as 64 percent of patients with this SGT result had two or more risk factors.

Logistic regression is a useful technique when the researcher wishes to explain the variation in a dichotomous outcome variable using dichotomous, ordinal, continuous, or a combination of explanatory variables, and when the

researcher needs to evaluate the association of one variable "controlled" for the effect of other potentially confounding variables. The authors appropriately described the independent variables associated with gestational diabetes in terms of statistical significance. Additionally, it is often useful to the clinician to convert the beta values into odds ratios by exponentiating the beta values. For example, the beta value for the continuous SGT result was 0.09, translating into a relative risk of 1.09 for every milligram per deciliter increase in SGT result. The standard error of the beta value can be used to test the significance of the association (as the authors did) by reporting P values, or by reporting the 95 percent confidence interval of the odds ratio, $e^{(\beta \pm 1.96\,SE)}$. Using the results for history of gestational diabetes in the regression model excluding SGT, the odds ratio for a positive history was 17.8 ($e^{2.88}$), with a 95 percent confidence inverval of 1.0 to 292.0 ($e^{2.88 \pm 1.96 \times 1.43}$).

The authors did not mention testing for significant interaction between explanatory variables. For example, might there be a synergistic or antagonistic interaction between increasing age and increasing parity in the risk of gestational diabetes mellitus? Potential interaction terms can be anticipated by calculating correlations between risk factors (generating a covariance matrix) and should be tested in the logistic regression model.

One final comment involves the inclusion of screening glucose tolerance test in the logistic regression model with other risk factors. It is not appropriate to control the effects of the risk factors of interest by the SGT results. In doing so, one compares the effects of historical risk factors at different levels of the SGT results. The SGT, measuring a similar biological system, is highly correlated with gestational diabetes and thus associated with the outcome variable; the SGT and gestational diabetes mellitus would have similar associations with risk factors. Thus it is not surprising that the association of the risk factors with gestational diabetes was not significant after controlling for the association with SGT results. Readers should perhaps focus on the analysis that excluded SGT from the logistic model and on the factors associated with a positive screening test.

Screening would be most effective if a high-risk group using historical risk factors could be defined. This study provides useful information toward solving this problem.

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