Primary, Secondary, and Tertiary Prevention
Program for Diabetes in Pregnancy

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Over the past 2 yr the effectiveness of a program in primary, secondary, and tertiary prevention of diabetes in pregnancy was studied. The purpose of the program was to determine the degree to which preventive medicine in terms of early screening and diagnosis, rapid initiation of treatment, and close follow-up surveillance could reduce the morbidity and mortality associated with pregestational and gestational diabetes. The study compared the program in prevention with previous programs, and its results were measured against national criteria established by the Centers for Disease Control. A significant increase in early identification of gestational diabetes and a decrease in fetal and maternal complications were detected.
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Diabetes during pregnancy is a significant public health problem impacting on >110,000 women (3% of all pregnancies; 1,2). Major acute complications of diabetes during pregnancy include hypoglycemia, ketoacidosis (associated with maternal and fetal mortality), and pregnancy-induced hypertension (3,4). Chronic maternal complications include diabetic retinopathy, nephropathy, coronary artery disease, and unstable metabolic control that, in turn, may lead to further exacerbation of the acute complications (5–7). Macrosomia, respiratory distress syndrome, hypoglycemia, hypocalcemia, hyperbilirubinemia, congenital malformation, and intrauterine death of the fetus have been associated with diabetes in pregnancy (8–12). Overall, diabetes in pregnancy results in a 10% risk of fetal morbidity and a 4% risk of fetal mortality (1,2).

We evaluated a comprehensive program in prevention established in a large urban medical center. The purpose of the study was to determine the extent that primary (education and counseling), secondary (screening), and tertiary (improved metabolic control) services would significantly reduce both maternal and fetal complications.

BACKGROUND

More than 2 million people reside in the Bronx and southern Westchester County, the communities served by the medical center. The male/female distribution in each county is 47 and 53%, respectively, with an estimated 150,000 women of childbearing age (13). The racial distribution among these women is 65% White and 35% Hispanic or Black (13). The incidence of type I (insulin-dependent) diabetes is 162/yr, with a prevalence of 4255 people. Among women of childbearing age served at the medical center, there are 8000 pregnancies each year of which an estimated 360 cases are classified as gestational diabetes.

In 1985, a model demonstration unit for detection and treatment of pregestational and gestational diabetes was established at the medical center with four aims: *1*) to develop a systematic and consistent approach to the identification of women with diabetes who are planning a pregnancy, earliest identification of pregnant women with pregestational diabetes, and the screening of all women between the 24th and 28th gestational wk; *2*) to rapidly diagnose gestational diabetes and institute

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treatment; 3) to optimize metabolic control and prenatal care to prevent maternal and fetal complications; and 4) to educate the community's health-care professionals so that screening, diagnostic, and treatment services are accessible to all individuals with diabetes in pregnancy.

PATIENTS AND METHODS

The Obstetrics Model Demonstration Unit (OBMDU) had seven major components: criteria for participation in the program, screening for high-risk cases, diagnostics, treatment, assessment for and treatment of complications, maternal and fetal follow-up, and training of health professionals.

Criteria for program participation. All women with diabetes who were planning a pregnancy or were of childbearing age were counseled to promote optimization of glycemic control as soon as possible. For women already under care at the medical center, this included careful monitoring of metabolic control, assessment of microvascular complications, and evaluation of other risk factors; for women treated outside of the center, this encompassed training of their health-care providers to institute tight control therapies at the community health-care delivery site.

For women with diabetes who were already pregnant, an evaluation of prepregnancy metabolic control was made with history, self-reported data, and existing laboratory tests. At entry, these women were placed on specially designed reflectance meters that contained memory microchips enabling the collection of verified ambulatory blood glucose values. For all women, independent of prepregnancy control, counseling concerning fetal and maternal complications was offered. In individuals for whom documented poor control (chronic hyperglycemia—average >200 mg/dl) existed and the complications of diabetes appeared severe, there was specialized counseling concerning the increased risk of possible fetal anomalies and maternal health consequences.

Screening. In accordance with the National Diabetes Data Group (NDDG), a 1-h screening oral glucose tolerance test (OGTT) was used (if >130 mg/dl, the individual was referred for a 3-h OGTT; 14). Although the screening test was given to all women between the 24th and 28th gestational wk, screening was administered independent of gestational week to those who met any of the criteria: obesity, maternal age >35 yr, family history of diabetes, and previous gestational diabetes.

Diagnosis. The diagnosis of gestational diabetes by NDDG criteria required a 3-h OGTT with the patient meeting or exceeding two values: fasting blood glucose 105 mg/dl, 1 h 190 mg/dl, 2 h 165 mg/dl, 3 h 145 mg/dl. Women were instructed to add the equivalent of 150 g of carbohydrate to their normal diet for each of 3 days preceding the test and to fast for the 12 h immediately before the morning OGTT. All women who tested positive were immediately evaluated for treatment.

Treatment. Because of the need to rapidly institute a treatment regimen that optimized metabolic control, the individual with gestational diabetes was evaluated immediately after diagnosis for insulin or diet-only therapy. For individuals with pregestational diabetes, insulin therapy was reassessed on entry into the program. Because glycosylated hemoglobin has been shown to be an inadequate marker of metabolic control in pregnancy, self-monitoring of capillary blood glucose (SMBG) with memory-based reflectance meters was employed.

For women with gestational diabetes, the determining factor for insulin treatment was based on a fasting OGTT >95 mg/dl and a mean blood glucose, achieved during a 3-day SMBG period, >95 mg/dl. In cases where glycemic control was or may have been difficult to achieve, hospitalization to establish euglycemia was considered. The criteria for hospitalization were presence of severe complications of diabetes, difficulty learning self-care in an ambulatory setting, or an initial need for extremely high doses of insulin.

Treatment for all patients began with an orientation/education program designed to help the individual with diabetes recognize the importance of diabetes in pregnancy and institute the regimen immediately. During orientation, all patients (independent of treatment modality) were taught SMBG techniques and given dietary instructions. For women placed on insulin regimens, insulin administration techniques were taught. The objective of therapy was to achieve euglycemia (fasting and postprandial blood glucose averaging <95 mg/dl) rapidly. Concurrently, patients at ideal body weight had to gain weight during pregnancy to ensure appropriate growth and development of the fetus. For obese individuals, weight management had to take into consideration fetal growth and development and maternal well-being (specifically pregnancy-induced hypertension). For individuals at ideal body weight, diet consisted of 35 cal/kg body wt; for those overweight but not obese, diet consisted of 30 cal/kg body wt; and for those who were obese (20% above prepregnancy ideal body wt), 25 cal/kg body wt was prescribed. Insulin dose varied based on whether the subjects were pregestational or gestational and based on their body weight, insulin reserve, and insulin resistance. A three-injection regimen (mixed NPH and regular in the morning, regular before dinner, and NPH at bedtime) with human insulin was prescribed according to the following general guidelines: 1) total dose calculated by 0.7 U insulin/kg body wt; 2) total dose divided into two-thirds for morning and one-third for evening administration; 3) morning dose administered in a 2:1 NPH-to-regular ratio; 4) evening dose administered in a 1:1 NPH-to-regular ratio with regular preprandial and NPH at bedtime. Further alterations in insulin and diet regimen were based on feedback from SMBG with a memory meter.

To accomplish near-normal glycemia, all patients were placed on the SMBG procedure. This procedure in-

cluded self-testing and coordinated clinical decision making between the patient and the clinician. To ensure accuracy and reliability of patient-generated data and to optimize clinical decision making, a computer-based patient management system was initiated on the OBMDU. The key components of this system were a memory-based reflectance meter (Glucometer M), a microcomputer to aggregate the data, and the Ambulatory Glucose Profile (15) to interpret the data. The memory-based reflectance meter was capable of storing blood glucose data (300 readings) with corresponding time and date of the test. Additionally, it could call back each reading; average all readings; and record (through a system of event markers) the time and date corresponding to meals, insulin administration, or intercurrent illness or symptoms of, for example, hypoglycemia. The microcomputer system aggregated the data stored by the meter and provided instant averages by hour, day, and period and provided an electronic log with each reading and corresponding time and date.

Assessment of complications. Screening for complications consisted of evaluation at the 16th gestational wk by amniocentesis for maternal α-fetoprotein for the individual with preexisting diabetes. If elevated or decreased, a repeat test was completed. If the amniocentesis confirmed the existence of a congenital malformation or chromosomal abnormality, the patient was immediately provided with genetic counseling. At the 20th gestational wk, ultrasound examination was completed to rule out existence of sacral agenesis, central nervous system (e.g., hydrocephalus) and cardiac (e.g., transposition of the great vessels) anomalies particular to diabetes.

For both the pregestational and gestational diabetic patients, evaluation for macrosomia and for fetuses small for gestational age began at the 28th gestational wk. This evaluation consisted of examination by ultrasound to calculate the femor-to-abdomen ratio, head-to-abdominal circumference ratio, and estimated fetal weight for a given gestational age. The measurements were repeated at the 32nd–33rd gestational wk and at the 37th gestational wk. When the tests indicated macrosomia or intrauterine growth retardation, intensive fetal surveillance was immediately initiated. Simultaneously, intensification of the diabetes regimen to further improve metabolic control was begun. Assessment for early delivery as a result of the presence of macrosomia was based on fetal lung maturity, fetal measurements, biophysical profile and velocity studies, and maternal metabolic control.

Maternal surveillance for the type I diabetic woman included continued monitoring for microvascular complications, assessment of metabolic control, and cardiovascular status. In type II (non-insulin-dependent) and gestational diabetes the main emphasis was on glycemic control. Additionally, evaluation of episodes of hyper- and hypoglycemia was made through biweekly assessment of the electronic log produced from memory-meter data. For both gestational and pregestational patients, special attention was placed on the early detection of pregnancy-induced hypertension (preeclampsia) and polyhydramnios.

The decision as to time of delivery was based on four factors: maternal hypertension, previous stillbirth, macrosomia, and poor compliance and/or metabolic control. The presence of any of these factors was indicative of the need for early delivery (37th–38th wk) after confirming lung maturation. All other patients were encouraged to achieve spontaneous delivery at term.

Maternal and infant follow-up. Postdelivery follow-up took two courses for the mother. When gestational diabetes resolved itself to normal levels of glycemia immediately after birth, the mother was asked to return for an OGTT at 6 wk and again at 6 mo after hospital discharge. Thereafter, OGTTs were repeated for each nondiabetic woman yearly. Women with pregestational diabetes and women whose blood glucose did not return to normal levels during hospitalization for delivery were advised to optimize metabolic control and assess and treat complications.

The infants of all patients were assessed at birth for Apgar score and glucose level. Within 72 h, additional evaluation included gestational age, evidence of macrosomia, and other diabetes-related morbidity, e.g., polycythemia. Examination over the next several years consisted of evaluation of physiological, psychomotor, and psychological development.

Training of health professionals. A program in education was instituted to train all health professionals affiliated with the medical center who were engaged in the care of women with diabetes in pregnancy. Professionals could participate in one of two programs depending on the level of their responsibility for clinical management. The basic level required acquisition of skills and knowledge related to etiology and classification; diet; pharmacology of insulin; psychosocial dynamics; antepartum, intrapartum, and postpartum complications; and management. Intensive training (≤1 yr) included the same areas with significantly greater depth and with a period of preceptorial training composed of rotations to each of the major disciplines (perinatology, medicine, nursing, and nutrition). During the rotation (1–2 mo) the trainee moved from observer to case manager. In the latter role, the trainee assumed overall responsibility for management of the diabetes in pregnancy including coordinating care with the general obstetrician.

Method of analysis. For the purpose of this study, data collected during the 2-yr period before initiation of the program was compared with data collected during the study. Between March 1984 and September 1985, a comprehensive evaluation of programs related to diabetes in pregnancy was undertaken at the medical center (16,17). The number of women screened and diagnosed with gestational diabetes was determined through chart audit, as was the assessment of the overall quality of care during their pregnancy. Additionally, all cases of diabetes before pregnancy (pregestational) that were

treated at the medical center were reviewed for prepregnancy counseling, level of metabolic control before and during the first trimester of care, and maternal and fetal complications during and after pregnancy. Prepregnancy counseling and patient education constituted the criteria for primary prevention. Secondary prevention criteria consisted of the implementation of screening and diagnostic testing. Tertiary prevention criteria were comprised of evaluation of complications and improvement of control.

RESULTS

Primary, secondary, and tertiary prevention in pregestational diabetes. During the period from January 1985 to June 1987, the OBMDU program identified 53 women with diabetes (42 type I, 11 type II). Of these women, 9% were seen before pregnancy, 80% were seen initially during the first trimester, and 11% were seen after the first trimester. Assessment of metabolic control and introduction of tight control regimens was possible with all of the latter patients. Based on these findings, the prevalence of pregestational diabetes in this population was estimated to be 5–7/1000 pregnancies, in contrast to earlier estimates of 2–2.5/1000, which were based on 1983–1985 study data.

Among the subjects with pregestational diabetes, 55% required hospitalization to improve metabolic control (to a mean blood glucose level of 80–95 mg/dl and a fasting blood glucose <95 mg/dl). These subjects entered the program with a mean (±SD) blood glucose of 250 ± 104 mg/dl. Patients treated on an ambulatory basis entered the program with a mean blood glucose of 189 ± 67 mg/dl. At the completion of the 1st wk of the program (either hospitalization or ambulatory management), mean blood glucose for the group was 103 ± 35 mg/dl as determined by memory-based reflectance meters. Pregestational subjects averaged 6.5 capillary blood tests/day (slightly higher during hospitalization). Throughout pregnancy, all patients with pregestational diabetes were maintained in good metabolic control (average blood glucose 93 ± 26 mg/dl). No comparable data were available for patients during the prior period (1983–1985).

Secondary and tertiary prevention in gestational diabetes. During the 18-mo study period, 10,500 pregnant women were screened between the 24th and 34th gestational wk, of whom 1340 were found to be positive and were scheduled for an OGTT. During the comparative period (1983–1985), 5400 pregnant women were screened. In our study, 293 women were found to have gestational diabetes (vs. 146 during the prior period). Of the women with gestational diabetes, 235 were diagnosed between the 24th and 28th gestational wk, 41 were diagnosed after the 34th gestational wk. In the previous study period, 85% of subjects were screened after the 28th gestational wk, with the remainder screened earlier.

During the 1st yr of the program, treatment for gestational diabetes was instituted within 10 days after confirmation of diagnosis. By January 1986, treatment was initiated no later than 5 days after diagnosis. For the 1st year (1984–1985), treatment was initiated in the hospital between 14 and 21 days after confirmation of diagnosis by OGTT. In our study, all subjects were placed on diet-only or insulin regimens and SMBG with memory meters. Of the 293 women with gestational diabetes, 52% required hospitalization for initiation of insulin therapy. Blood glucose values pre- and posthospitalization were compared with values for those not requiring hospitalization. Those requiring hospitalization had an average fall of 40 mg/dl to achieve a mean posthospitalization blood glucose of 95 mg/dl. Individuals placed on diet-only regimens had a reduction in average blood glucose after the 1st wk of treatment of 20 mg/dl to achieve a mean postinitiation of treatment blood glucose of 89 mg/dl. As in the case of the pregestational diabetic subjects, these patients were maintained in good control (defined as preprandial blood glucose of 85–95 mg/dl) throughout their pregnancy. (Comparable data for the earlier period were not available.)

Metabolic control throughout pregnancy was also monitored by glycosylated hemoglobin values. When these values were compared with those obtained through daily self-monitoring, a correlation coefficient of $r = .52$ ($P = .006$) with no difference for gestational or pregestational diabetes was found (18,19).

Fetal-mortality data collected for the 18-mo period of this program showed no significant difference in the rate of spontaneous abortion (20%) for subjects with pregestational or gestational diabetes. All but one individual with gestational diabetes delivered live births. With respect to fetal morbidity, we noted that among the pregestational diabetic patients there were six cases of fetal anomalies, consisting primarily of cardiac and central nervous system disorders. In contrast, there were eight cases of fetal anomalies among the gestational diabetic group. In addition, macrosomia was identified among 15% of the women with gestational diabetes. Fetal complications for both groups included 15% hypoglycemia, 12% polycythemia, 8% hyperbilirubinemia, and 2% hypocalcemia. Maternal complications revealed 9% premature deliveries and 20% pregnancy-induced hypertension. Analysis of the method of delivery in gestational and pregestational diabetic women showed that 84% had spontaneous vaginal deliveries, and 16% underwent cesarean section. In contrast, the 1983 patient period showed 34% macrosomia. [Other data were unavailable (20).]

Follow-up was possible for 70% of the women with gestational diabetes and 100% of the women with pregestational diabetes after delivery. At 3 mo postpartum, four patients were screened positive for type II diabetes; two were diagnosed with type II diabetes. These women, along with those with pregestational diabetes, were referred for treatment. Between 6 and 12 mo postpartum, eight additional women were identified as diabetic. No

follow-up of women with gestational diabetes during the 1984–1985 period was found.

DISCUSSION

The prevalence of pregestational diabetes has been reported by various sources in the past to be between 2 and 71/1000 pregnancies, depending on diagnostic criteria and maternal age (1). Currently, it is estimated that 4–15/1000 pregnancies occur in women who have diabetes before pregnancy (most being type I; 1). Estimates of the prevalence of gestational diabetes range from 25 to 200/1000, again depending on criteria for diagnosis and maternal age (1). Recent investigators have placed the prevalence at 25–50/1000 pregnancies. The likelihood of maternal or fetal complications among women with pregestational and gestational diabetes has been estimated to be four–five times that of nondiabetic women. The likelihood of developing type II diabetes within 5 yr of diagnosis of gestational diabetes when compared with age-matched control subjects is 20:1. Because of these factors, diabetes in pregnancy must be considered a major public health problem. This problem was addressed through the development of a health-care delivery system designed to identify women with diabetes who were planning pregnancy, to screen all pregnant women, and to initiate treatment as rapidly as possible to prevent adverse fetal and maternal outcomes. In 1986, criteria for "enhancing diabetes control through maternal and child health programs" were published by the Centers for Disease Control (21). Five specific program elements were set forth: "1. screening of women to detect gestational diabetes; 2. identification of women with established diabetes who may become pregnant; 3. insurance of appropriate care for women with diagnosed diabetes (either established or gestational) on-site or through referral; 4. postpartum follow-up and continuing care of women with established diabetes to maintain good blood glucose control before pregnancy and throughout subsequent pregnancies; and 5. postpartum follow-up of women with gestational diabetes to detect previously undiagnosed established diabetes, to monitor the maintenance of ideal body weight to reduce the chance of developing diabetes later in life, and to ensure prompt diagnosis of diabetes if and when it develops."

Serving a diverse population from two large counties, we were able to identify that 290 women had diabetes in pregnancy. Of this group, ~32/1000 women had gestational diabetes, which is consistent with national estimates of 25–50/1000 pregnancies (1). The prevalence of pregestational diabetes was ~5/1000 pregnancies (consistent with national estimates of 4–15/1000 pregnancies). The absence of any maternal deaths and the few maternal complications (hydramnios, toxemia, and related hypertension and renal disease) were found to be consistent with national data. Fetal morbidity and mortality were found to be in the lower range of national estimates. Although the number of deliveries was too small to conclude that the system of health-care delivery established at our center provides an above-average fetal outcome rate, our data do suggest that for congenital anomalies, i.e., macrosomia, hypocalcemia, polycythemia, and respiratory distress syndrome as well as fetal and neonatal death, intensive prenatal care and tight metabolic control are effective interventions.

The concept of community-based prevention in diabetes and pregnancy is an important factor to ensure gains in reduction of maternal and perinatal morbidity and mortality. Attention has been focused on the preconceptional period as offering the most opportunities for primary prevention services. Planned pregnancies among women of childbearing age with preexisting diabetes provide the best opportunity to ensure a normal pregnancy and delivery. Dietary counseling for obese women planning pregnancy may be a factor in reducing the incidence of gestational diabetes. These prevention activities during the preconceptional period must be coincident with secondary prevention during the interconceptional phase. Screening for gestational diabetes followed by rapid diagnosis and initiation of treatment is the best method of ensuring prevention of macrosomia and other maternal and fetal complications of pregnancy. Finally, the combination of primary and secondary prevention is likely to decrease the extended hospitalization and follow-up treatment of women with pregestational or gestational diabetes who present late in their pregnancy. It remains to be determined whether extensive primary and secondary prevention services will be cost saving. We already know that such services, from a human perspective, are greatly beneficial.

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