Review

Nutritional Management in Diabetes and Pregnancy

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During pregnancy it is necessary for the mother with diabetes to maintain careful control of the diabetes in order to lessen both fetal and maternal morbidity and mortality. The diet must take into account not only the metabolic requirements of the mother, but also those of the developing fetus. A total weight gain of 22 to 26 pounds is recommended, with the pattern of weight gain being more important than the total amount. Pregnancy is not a time for weight reduction. Caloric requirements can be met by the addition of 300 kcal. per day to the prepregnancy meal plan, or about 36 kcal. per kilogram. This can be met by the addition of 50 gms. carbohydrate and 30 gms. protein. Diets will contain approximately 1800 to 2500 calories a day. Calcium, iron, folic acid, and sodium also require attention in meal planning. The importance of regular meals and snacks must be emphasized. In particular, bedtime snacks are important because of the tendency towards overnight hypoglycemia and ketosis. DIABETES CARE *1*: 264–270, JULY–AUGUST 1978.

Recently there has been an increased awareness of the role of nutrition during pregnancy. Fetal nutrition is dependent on that provided by the mother, and this is true whether or not the mother has diabetes. In the diabetic mother, however, we also need to monitor closely the control of diabetes, including specific nutritional concerns.

Pregnancy should not be considered until the diabetes is under good control, and a large part of control relies on diet. If the mother finds she is pregnant before she has had an opportunity to regulate her diet properly, she should do this immediately.

WEIGHT GAIN DURING PREGNANCY

The previous recommendation for weight gain during pregnancy for mothers with diabetes was 8 to 10 kg. (18 to 22 pounds).[1] We now realize that this may be inadequate and thus is not in the best interest of the fetus or the mother. Current recommendations are for weight gain of 10 to 12 kg. (22 to 26½ pounds), distributed in an appropriate pattern. However, we frequently find that diabetic mothers will gain weight more rapidly and gain more than 26½ pounds. This increased weight gain may be due to fetal macrosomia and to abnormally large placentas.[2]

Figure 1 shows the normal pattern of weight gain throughout pregnancy.[3] The usual pattern of gain consists of 1 to 2 kg. during the first trimester, and then a progressive linear rate of gain averaging 350 to 400 gms. per week (approximately 14 ounces or slightly less than 1 pound) throughout the last two-thirds of gestation. Such a course will result in a total gain of 10 to 12 kg.

The normal pattern of weight gain is sigmoid in shape, showing a small gain during the first trimester, a rapid increase during the second, and a slowing in the rate of increase during the third. Weight gains in this range are most consistent with the most favorable outcome of pregnancy, and a weight reduction program that distorts normal gain should not be imposed during pregnancy.[4]

It is more important to consider the pattern of weight gain during pregnancy than a specific total weight gain appropriate for all pregnant women. The patient who gains 10 kg. during the first trimester and then limits the total weight gain during the rest of the pregnancy to 1 to 2 kg. will need to starve herself. This may result in serious nutritional deprivation for both mother and fetus, which may have permanent damaging effects on the child. On the other hand, the mother who gains a minimal amount during the first two-thirds of the pregnancy and then gains 11 kg. rapidly before delivery can in no way compensate for the damag-

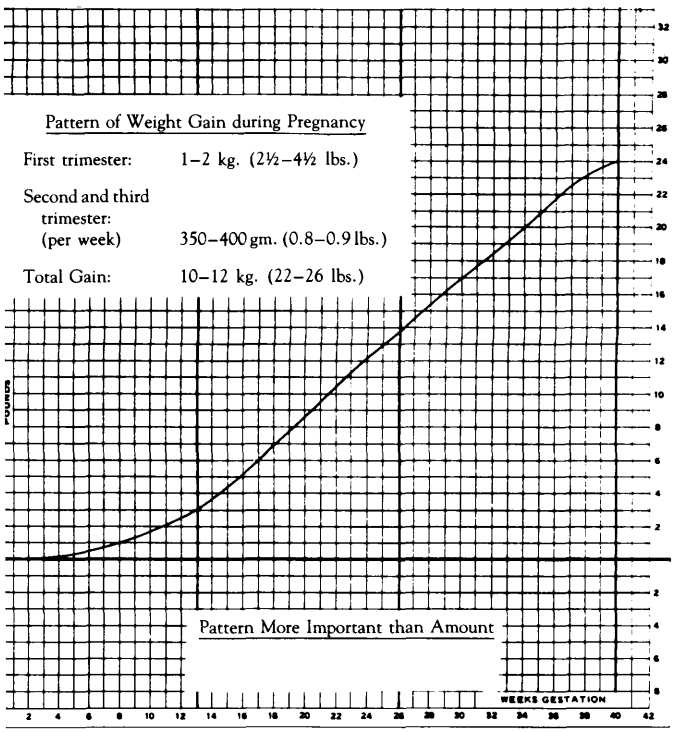

FIG. 1. Prenatal gain in weight. (From the Committee on Maternal Nutrition, Food and Nutrition Board, National Research Council, National Academy of Sciences; reprinted with permission from Clinical Obstetrics, J. B. Lippincott Co., 1953.)

ing effects of nutritional deprivation already experienced during the first and second trimesters.[5]

There is a strong relationship between maternal weight gain and infant birth weight. Inadequate weight gain during pregnancy may result in fetal growth retardation. The age-old concept of the fetus as a "perfect parasite" has been challenged by Rosso.[6] In a series of animal experiments, he has demonstrated that the rat placenta undergoes a progressive maturation during the latter part of pregnancy and this maturation is essential for normal transport of nutrients from mother to fetus. Maternal malnutrition decreases the capacity to transfer glucose and amino acids across the placenta. This results, in animals, in fetal death and fetal growth retardation. Thus, the mother keeps a higher percentage of nutrients than she normally would. This can be seen if one examines the effect of malnutrition on maternal and fetal body weight. Fetal weight is always reduced proportionally more than maternal weight. In humans, available data suggests that the same is true. Thus, the fetus is directly responsive to maternal status and, for proper growth, is dependent on adequate dietary intake by the mother.

Maternal complications are frequently associated with obesity or underweight at the time of conception and with wider deviation from normal rate of weight gain during pregnancy. Many slender women may need to gain more than the average 25 pounds. The key consideration is development of healthy tissue at a smooth, progressive growth rate, irrespective of the total gain, and that maternal health remain good.

DISTRIBUTION OF WEIGHT GAIN

Figure 2 shows the distribution of weight gain. Weight gain is divided between the maternal compartment and the fetal compartment consisting of the fetus, placenta, and amniotic fluid.

Maternal Compartment Weight Gain

In the early part of pregnancy the fetus gains hardly more than one gram of weight per day. By contrast, maternal tissues are growing rapidly during this time. The uterus and breasts enlarge, maternal blood volume expands, and the placenta and amniotic fluid are formed.

Maternal stores of fat increase very rapidly before midpregnancy, and such storage slows down and appears to cease before term. This fat deposition is mostly at central rather than peripheral sites: abdomen, back, and upper thighs. Thus, the mother stores some nutrients before the period of greatest fetal growth. These reserves may act to safeguard the fetus against nutritional inadequacy in the subsequent months of pregnancy.[4]

During the second and third trimesters, there is an increase in maternal blood volume. During the third trimester there is also weight gain in the mother through accumulation of extracellular fluid.

The weight gain then in the maternal compartment (see table 1) will be approximately 6 to 7 kg. (13 to 14 pounds). Changes in the mother are primarily in preparation for lactation, the most important being the deposition of up to 4 kg. of fat.[4]

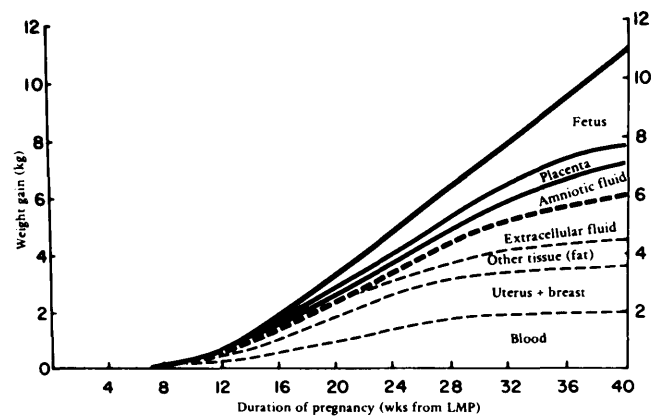

FIG. 2. Average pattern and components of maternal weight during pregnancy. (Reproduced with permission from Nutritional Support of Medical Practice, Harper & Row, 1975.[3])

TABLE 1
Weight gain during pregnancy

	Weight gain		
	kg.	lb.	
Maternal compartment			
Blood volume	2	4	
Uterus and breasts	2	2.9	(= uterus 2.0 +
Fat	1–2	3.5	breasts 0.9 = 2.9)
Extracellular fluid	2	2.7	
Total	7	14	
Fetal compartment			
Fetus	3.4	7.7	
Placenta	0.6	1.4	
Amniotic fluid	1.0	2	
Total	5.0	11	

Fetal Compartment Weight Gain

For the first through the fourth months, the daily need for nutrients by the fetus is so small as to be practically negligible. By the sixth month, the fetus is gaining about 10 gms. daily, and about half the total weight increase of the fetus during gestation occurs in the last two months. Some 5 kg. (11 pounds) are gained in the fetal compartment (table 1). Approximately 3.4 kg. are in the fetus, about 0.6 kg. in the placenta, and about 1.0 kg. is amniotic fluid.[7]

Research in animals has shown that fetal growth occurs in three phases: (1) hyperplasia—growth occurs through rapid multiplication of the number of cells (cellular proliferation); (2) combined hyperplasia and hypertrophy—growth through hyperplasia continues, but also with enlargement of cell size; and (3) hypertrophy—cell size increases but hyperplasia stops. Different organs attain full cell numbers at different ages; lungs and brain are among the first to reach full cell count.[8] Hyperplasia is curtailed by nutritional deprivation. Provision of an excellent diet after conclusion of the hyperplasia process contributes to the enlargement of individual cells, but cell numbers can no longer be increased. If animals are fed well throughout hyperplasia, tissues attain normal cell count. If the animals are then starved, hypertrophy does not occur. When adequate diet is restored, the hypertrophic process resumes and progresses normally. It therefore appears that nutritional adequacy throughout the hyperplastic phases is most crucial.[9]

NUTRIENT NEEDS DURING PREGNANCY

Calories

The total energy cost of pregnancy, calculated from the amounts of protein and fat accumulated by the mother and fetus and the additional metabolism incurred by these tissues, amounts to approximately 75,000 calories. This amounts to an increased requirement of 300 calories per day which is approximately 15 per cent above the average nonpregnancy requirement. The simplest way to assess calorie intake is to monitor weight gain.[4]

The needed increase is less than 300 calories per day early in pregnancy and may be higher than 300 calories per day near term, although increased need for calories is relatively consistent throughout the last two trimesters.[5] The increased requirements late in pregnancy may be partially offset by a tendency to diminish physical activity late in pregnancy.

Emerson et al.[2] examined calorie cost during diabetic pregnancies. For patients with chemical diabetes presenting during pregnancy with an abnormal glucose tolerance test (White's class A[10]), the calorie expenditure values per day are slightly, but not significantly, higher than for nondiabetic controls (figure 3). In the pregestational insulin-treated diabetic patient, however, daily caloric expenditure rises more rapidly than in the controls and reaches a significantly higher cumulative total at 36 weeks gestation than the controls at 40 weeks. These are increments in calorie expenditures per day above pregravid calorie expenditures. Emerson proposed that the increase of available energy in diabetic mothers would induce more rapid growth, which might lead to early maturation of the fetus, thus suggesting a rational basis for the common practice of performing early deliveries in diabetic pregnancies.

Caloric level will be dependent on maternal age, activity, height, prepregnancy weight, and stage of pregnancy. The best way to determine if calorie level is appropriate is to individualize the diet and then check weight gain to be sure that calories are adequate. The diet should contain approxi-

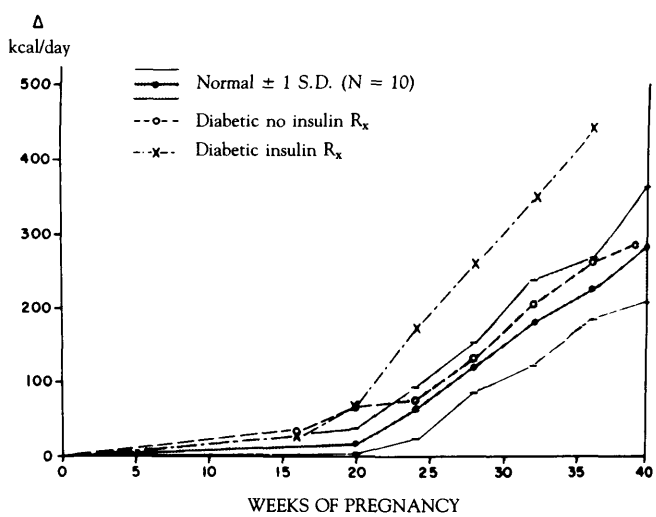

FIG. 3. Increment in caloric expenditure per day. (Reproduced with permission from: Emerson et al., Obstet. Gynecol. 43: 354–62.[2])

TABLE 2
Nutrient needs during pregnancy

Nutrient	Needs during pregnancy	Requirements	Sources
Calories	300 kcal./day above nonpregnancy needs (15%)	36 kcal./kg. desired body weight	CHO and protein additions; CHO, 50 gms., and protein, 30 gms.
Carbohydrate	50 gms./day above nonpregnancy needs	45–50% calories (150–250 gms.)	Additional two breads, two fruit exchanges
	30 gms./day above nonpregnancy needs	20% total calories (75–125 gms.) 1.3 gms./kg. mature woman 1.5 gms./kg. adolescents 1.7 gms./day young girls	Additional two non-fat milk, two meat exchanges
Iron	870–880 mg. needed during prepregnancy (250–300 mg. fetus and placenta) (500 mg. mother)	18 mg./day	Liver, eggs, enriched grain and cereal products
Folic acid	200–400 μg./day above non-pregnancy needs	800 μg./day	Liver, leafy green vegetables, whole grain bread, orange and grapefruit juices
Calcium	400 mg./day above nonpregnancy needs (Fetus needs 200–300 mg./day during last trimester.)	1,200 mg./day	1 quart milk (vitamin D fortified), cheese, leafy green vegetables

mately 36 calories per kilogram of desired body weight. Thus the average 58 kg. (128 pound) woman between the ages of 19 and 22 years should ingest approximately 2100 calories daily throughout pregnancy (see table 2).

Pregnancy in teenage girls presents a situation of particular stress because the needs of the developing infant are superimposed on the mother's own needs for adequate growth and development. Maternal and infant complications occur about twice as frequently among early teenage mothers as among mature women. The best determination of proper caloric intake in teenagers is to monitor weight gain.

Carbohydrate

Meticulous control of maternal blood glucose by diet and insulin is central to the management of the diabetes during pregnancy in order to prevent fetal hyperinsulinemia with its stimulus to excessive growth and lipogenesis and the associated increase in perinatal mortality. The fetus uses approximately 50 gms. of glucose a day. Since the fetus will extract glucose from the maternal blood to utilize as substrate, the mother's system may be forced to burn relatively more fat than usual, thus increasing the tendency to develop ketosis. Acetonuria during pregnancy has been correlated with increase in number of stillbirths and lower IQ of the offspring.[11–12] The diabetic mother in general tends to use a greater than normal proportion of carbohydrate in her metabolic fuel mixture.[2] Therefore, the carbohydrate in the meal plan should be increased by a minimum of 50 gms. per day. Inadequate calories or carbohydrate in the meal plan necessitating the catabolism of fat can be factors in the cause of maternal acetonuria. This also points to the danger of imposing calorie restriction during pregnancy.

Protein

Protein is required in increased amounts during pregnancy to provide for the fetal needs and to meet the required maternal needs of expansion of blood volume and growth of breasts and uterine tissues. Nitrogen balance studies suggest that 30 gms. of protein per day should be added to the pregravid protein requirements.[13] Total daily protein intake during pregnancy for the mature woman is 1.3 gms. per kilogram of body weight; for the adolescent, ages 15 to 18, 1.5 gms. per kilogram; and for younger girls 1.7 gms. per kilogram.[4] The increase in protein should be added during the second month of pregnancy. About two-thirds of the protein should be of high biological value, such as eggs, milk, meat, or soy protein.

Iron

The pregnant woman requires additional iron for two reasons: increased blood volume and increased need to supply iron to the fetus and placenta. Blood volume shows little increase early in pregnancy, increases rapidly during the second trimester, and stabilizes late in the third trimester. Peak blood volume before delivery is about 50 per cent

greater than nonpregnancy volume. By comparison the total erythrocyte quantity increases only 20 to 30 per cent. If iron supplements are not given the maximum increase of erythrocytes will be 20 per cent, but if adequate iron is available the increase is still only 30 per cent.[5]

The mother must also supply iron to the fetus and placenta. If the mother's diet is rich in iron during pregnancy, the child will be born with a liver well stored with iron, often a reserve sufficient to last through the months when the child is fed chiefly milk. With respect to iron, the fetus is something of a parasite and will get priority, actually tapping the mother's iron reserve.

A total of 870 to 880 mg. of additional iron will be needed during the pregnancy; the fetus and placenta contain 250 to 300 mg. of iron and the expanded blood volume of the mother 500 mg. This is a requirement of 18 mg. of iron per day and usually cannot be met by foods unless liver is eaten once or twice a week.

Folic Acid

Folate deficiency is common during pregnancy, although not as common as iron deficiency. The need for folate is approximately doubled; this being about 800 μg. during the second and third trimesters. It is theoretically possible and probable that the folate needs can be met by the diet since folic acid is so widely distributed in foods.[5]

Folic acid forms coenzymes involved in synthesis of nucleic acids. At times of rapid cell division, such as during pregnancy, there is a sharp rise in the need for folic acid because the production of nucleic acids is very rapid.[14] Folate is also essential for formation of red blood cells in both mother and fetus. Depletion of folic acid can occur after multiple pregnancies, and this can be compounded if the mother is on oral contraceptive pills between pregnancies.[15]

Calcium

Maternal serum calcium levels will fall during pregnancy, even if the pregnant woman receives adequate dietary calcium, partly as a result of physiologic hemodilution. During the last trimester of pregnancy, calcium is deposited in the fetus at a rate of 200 to 300 mg. daily. Throughout pregnancy the efficiency of intestinal calcium absorption is increased. Although the optimum intake is far from resolved, a daily intake of 1,200 mg. is recommended.

Vitamin D is important along with calcium during pregnancy because of its role in promoting calcium absorption; it is necessary for deposition of both phosphorus and calcium in the bone. Sufficient quantities are found through the use of vitamin D-fortified milk and through regular exposure of skin to sunlight.[5]

Sodium

A number of physiologic facts in pregnancy result in the tendency towards increased sodium excretion. There is increased glomerular filtration during pregnancy of about 60 per cent over nonpregnancy levels, and this could result in excessive loss of sodium were it not that the adult kidney has the ability to salvage much of the sodium presented to it. An insufficient intake of sodium may, therefore, place excessive stress on the normal sodium conservation mechanism. Instead of restriction there is now concern to supply sufficient sodium in order to minimize intravascular volume contraction.[16]

Sodium is required during pregnancy for the expanded maternal tissues of the fluid compartments as well as to provide for fetal needs. The older traditional view has been that the pregnant woman is an insidious salt retainer in whom sodium is apt to increase vascular activity and predispose to preeclampsia. This is being challenged by the current theory that the pregnant woman is a salt loser who, if adequate sodium intake is not maintained, becomes hyponatremic.[17] Some obstetricians currently recommend bed rest with the patient lying on her side to improve renal flood flow, rather than salt restriction.[10]

Other Nutrients

The need for other vitamins increases in small amounts during pregnancy and can be satisfied in a balanced diet. The advisability of vitamin supplements is a controversial issue; supplements are probably unnecessary, but when taken according to directions will most likely do no harm.[4]

LACTATION

The mother with diabetes, if she chooses, should be able to nurse her baby. Given the quantity of milk consumed by a normal infant, a lactating mother must take in 600 to 800 calories above her normal dietary intake. However, if she increases her intake by 500 calories she will consume some of her body stores which have been laid down as fat during pregnancy.[18] Breast feeding can be an excellent way to lose fat stored during gestation, and if properly monitored might prove to be a good way to lose excess fat that was present before pregnancy.

Breast milk is amazingly constant in composition. Both marked excess and marked restriction of water intake reduce the quantity of milk. Reduced calories, protein, carbohydrate, and fat do the same but the composition changes very little. By contrast, vitamins and minerals in the maternal diet are reflected in their concentration in breast milk. For this reason, extra attention should be paid to assure adequate intake of calcium and vitamins A and D.

Approximately 200 to 300 mg. of calcium and 8 to 12 gms. of protein are contained in each day's production of breast milk. Consumption of one quart of milk daily will provide these needs of the nursing mother. Iron supple-

mentation should be continued to replenish maternal stores.[18]

The average weight loss with delivery and during the first week postpartum is 8 to 9 kg. (18 to 20 pounds). Weight loss is then gradual so the weight gain of pregnancy is lost entirely by three months. If weight reduction is necessary, it may be instituted after lactation or two or four weeks postpartum. It is important to correlate insulin dosage with the calorie level of the diet.

MEAL PLANNING

Nutritional requirements are the same for the diabetic mother as for the nondiabetic mother. The problem is to provide these nutrients in a pattern throughout the day in an attempt to coincide with the time course of action of exogenously administered insulin. Distribution also aims to minimize the uncomfortable effects of hypoglycemia. Fetuses are, however, remarkably tolerant of hypoglycemia, and prevention of acidosis becomes much more important, especially during the last three months.[10,19]

The importance of regular meals and snacks must be emphasized. In particular, bedtime snacks are important because of the tendency towards overnight hypoglycemia and ketosis. At least 25 gms. of carbohydrate should be provided at bedtime. In gestational diabetes, diet alone frequently will maintain relatively normal glucose levels.

Starvation ketosis and diabetic ketoacidosis are enhanced in pregnancy as a result of the switch from the fed to fasting state induced by the fetus as well as by the diabetogenic effects of pregnancy itself. Starvation ketosis usually occurs early in pregnancy and is characterized by normal or low blood sugar levels together with ketonuria. More fuel (food) is needed. Diabetic ketoacidosis is characterized by elevated blood sugars in combination with glycosuria and ketonuria and results from severe insulin deficiency.[20]

During the first 3 to 4 months the prepregnancy diet will need to be increased by 300 to 400 calories. This should be done by increasing the carbohydrate intake by 50 gms. and the protein by 30 gms. Carbohydrate needs can be met by adding two additional breads and two fruit exchanges, and the protein needs by the addition of two skim milk and two meat exchanges. It will be important to divide the meal plan into three fairly equal meals with at least three snacks.

The distribution of calories will be: 45 to 50 per cent carbohydrate (150 to 250 gms.), 20 per cent protein (75 to 125 gms.), and 30 to 35 per cent fat (rest from fat). It is important to monitor the weight gain. If weight gain is too rapid, cut the calories from fat in the meal plan. Distribute the carbohydrate fairly evenly throughout the day. See table 3 for a sample diet prescription.

The ideal meal plan would, therefore, include the following: one quart skim milk or yogurt; one serving of dark leafy vegetables; frequent use of fruit, one high in vitamin C; one large or two small servings of meat, fish, or poultry with the frequent use of liver; one egg daily or at least five per week; four slices of whole grain bread—cereal, potatoes, macaroni, or spaghetti may be substituted; and two tablespoons margarine or vegetable oil. Milk should be fortified with vitamin D, and iodized salt should be used in cooking and at the table.

If severe fluid retention or hypertension develops in the mother with diabetes, it may be necessary to reassess dietary sodium intake. Sodium restriction may be needed, usually to 2 gms. per day.

TABLE 3
Distribution of calories in the diabetic meal plan during pregnancy

	Meal plan		Sample diet prescription	
Nutrient	Distribution of calories (%)	Amount (gm.)	Distribution of calories (%)	Amount (gm.)
Carbohydrate	45–50	150–250	48	250
Protein	20	75–125	20	110
Fat	30–35	Balance*	32	75

* Cut fat if weight rises too fast.

SUMMARY

The normal pattern of weight gain will be approximately 22 to 26½ pounds. This, however, may be increased in the mother with diabetes. The pattern of weight gain will be more important than the amount. The diet during pregnancy will need to be increased by 300 to 400 calories per day. This can be met by the addition of 50 gms. carbohydrate (two bread and two fruit exchanges) and 30 gms. protein (two meat, two skim milk exchanges). If weight gain is too rapid, cut back on the fat intake. Calcium, iron, and folic acid are additional nutrients that are required in larger amounts during pregnancy.

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