Epidemiology of Spontaneous Premature Rupture of Membranes: Factors in Pre-Term Births

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The frequency of spontaneous premature rupture of membranes (PROM) was determined in the pregnancies of 1,848 white mothers and their singleton infants, born at the University of Kansas Medical Center between April 1975 and April 1978. The frequency of PROM increased significantly from a low of 34/707 (4.8 percent) among low-risk mothers, to 40/444 (9.0 percent) among mothers smoking one to 60 cigarettes a day, to 212/204 (10.3 percent) among mothers with multiple adverse maternal practices, and to 12/46 (26 percent) among mothers with selected complications of their pregnancies.

The proportion of low birth weight (LBW) (<2,500 g) pre-term infants born to PROM mothers increased among the risk factor groups in a similar manner, from a low of 2/34 (6 percent) in low-risk pregnancies to 8/40 (20 percent) among mothers smoking one to 60 cigarettes a day, to 7/21 (33 percent) among mothers with multiple adverse practices, and to 7/12 (58 percent) among mothers with selected complications of pregnancy.

The increased incidence of low birth weight pre-term infants born to mothers with PROM was associated with evidence of growth retardation among full-term infants in the high-risk groups. This finding was manifested by reductions in mean birth weights of full-term infants born to high-risk mothers but not observed in full-term infants born to low-risk mothers. The attained growth at birth of low birth weight pre-term infants could not be determined, because appropriate birth weight standards for pre-term infants born to mothers with low-risk pregnancies are not available.

These results suggest that growth retardation in fetuses increased the probability of the mothers having PROM prior to the onset of labor, and, if PROM did occur, of having a premature delivery. We hypothesize that the tensile strength of the amnion and chorion is diminished by the same conditions that retard fetal growth, and that this reduction in strength of the fetal membranes contributes to premature rupture of membranes and pre-term delivery.

INTRODUCTION

Modern technology has improved the survival rate of pre-term infants under 1,500 g at birth at a heavy financial cost and at a considerable risk of long-term deficits among survivors. Comparatively little progress has been made in preventing pre-term births. Guidelines for Perinatal Care, second edition, states that the main cause of perinatal deaths among small pre-term infants is spontaneous premature rupture of membranes (PROM), and that the cause(s) of PROM remain unknown [1]. A variety of causes have been suggested: infection, trauma from pelvic examinations or coitus, polyhydramnios, weakened membranes, or incompetent cervix [2]. Changes in barometric
pressure or some "circadian factor" have also been implicated [3]. Relatively little effort has been made to determine how unfavorable maternal behavior, such as cigarette smoking or abuse of alcohol and addicting drugs, might be associated with PROM. In an epidemiologic study published over a decade ago, a threefold increase in pre-term births under 34 weeks' gestation was observed among cigarette smokers with PROM as compared to non-smokers with PROM; however, smokers and non-smokers in the study were not clearly defined [4]. Smokers and non-smokers often adopt other unfavorable practices, such as gaining too little weight during pregnancy, being too young, going without any professional prenatal care, or abusing alcohol and other drugs. The present study was undertaken to determine outcomes in pregnancies that were complicated by PROM combined with a variety of risk factors. Comparisons were made between outcomes of pregnancies complicated by PROM combined with other risk factors and the outcomes of pregnancies complicated by other risk factors except PROM. Particular emphasis was placed on outcomes of pregnancies complicated by maternal cigarette smoking during pregnancy, with and without PROM. PROM did occur among mothers with low-risk pregnancies and with medical or obstetric complications of pregnancy, and the outcomes of these pregnancies were also investigated.

METHODS

The study group consisted of 1,848 white mothers who delivered singleton infants at the University of Kansas Medical Center from April 1975 to April 1978. These were the same mothers and infants who appeared in our previous studies of low birth weight (LBW) [5–7]. Only white mothers were used because the group of black mothers was much smaller, and the socioeconomic status (SES) was very different.

The mothers were drawn from a wide range of socioeconomic circumstances, ranging from professional and executive levels to unemployed and welfare groups, from those who were college-educated to those with only primary school education, and from both married and unmarried mothers.

The methods of data collection on mothers and infants also were the same as those described in our previous studies. Briefly, these methods included the classification of mothers into low- and high-risk groups, using a special protocol. Four categories of high risk were established (Table 1): environmental conditions, fetal conditions, medical and obstetric complications of pregnancy, and adverse maternal practices. Mothers with high-risk pregnancies were assigned to one of the four categories as follows: those with environmental conditions were assigned to category 1 regardless of other risks present (no mothers in the present study were assigned to category 1); mothers were assigned to category 2 (fetal conditions) even if medical and obstetric complications and/or adverse practices were present; they were assigned to category 3 (medical and obstetric complications) even if adverse practices were present; and they were assigned to category 4 (adverse maternal practices) if they had adverse maternal practices but none of the risks in categories 1, 2, or 3 during their pregnancies. If the pregnancies had none of the risk factors in Table 1, they were assigned to the "low-risk" group.

Two subsets of the mothers with medical/obstetrical complications were created: those with medical/metabolic complications, and those with uterine or placental abnormalities. Also, for the analysis here, the group of "adverse practices" was divided into subsets: those mothers who smoked cigarettes throughout pregnancy but had no
TABLE 1
Risk Conditions Associated with Low Birth Weight*

1. Environmental Factors
   - High altitude
   - Exposure to specific toxic agents
2. Fetal Factors
   - Multiple births
   - Congenital malformations
   - Fetal infections
   - Inborn errors of metabolism
   - Maternal-fetal blood incompatibility, producing disease in the fetus
3. Medical Complications of Pregnancy
   - Toxemia of pregnancy
   - Chronic hypertension
   - Severe vaginal bleeding in third trimester
   - Abnormally high glucose tolerance curves
   - Malformations of placenta, cord, or uterus
   - Anemia: hemoglobin level < 10 g/dL
   - Severe chronic maternal disease
   - Leukemia
   - Malignant solid tumors
   - Large ovarian cysts or uterine fibroids
   - Continuous maternal medication with corticosteroids or immunosuppressive, teratogenic, or fetal-growth-retarding drugs
   - Polyhydramnios or oligohydramnios
4. Adverse Maternal Practices
   - Cigarette smoking during any part of pregnancy
   - Low weight gain in trimesters 2 and 3
   - Low weight for height at conception
   - Delivery < 17 years of age
   - Delivery > 34 years of age
   - No professional prenatal care
   - Use of addicting drugs or consumption of large amounts of alcohol during pregnancy

*Low weight gain, < 228 g per week in trimesters 2 and 3
*Low weight, > 15 percent below normal Sargent's table for young women (J Nutr 13:318, 1963)
*PROM was considered a special risk that occurred in each of the four high-risk categories and also in low-risk pregnancies.

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other risk factors, and those mothers who had multiple adverse practices, usually smoking plus one other.

The term “adverse practices” was used for risk factors that were under the control of the mothers, such as the age at which they became pregnant, their weight or weight gain, and behaviors such as cigarette smoking. The diagnoses of PROM and of medical and obstetric complications of pregnancy were made by the attending physician in each case and were obtained from the mothers’ obstetrical records. All deliveries were made by senior staff and resident staff physicians of the University of Kansas Medical Center. The pediatric investigator (HCM) examined and measured all infants, reviewed the mothers’ medical and obstetric records, and interviewed all mothers between delivery and discharge from the Medical Center to obtain the history of cigarette smoking during pregnancy and to clarify information pertaining to any data included in this study.
The diagnosis of pre-term and full-term births was made from a composite of observations: obstetricians' examinations of the mothers, pediatric examination of the infants, calculated gestational ages, and Dubowitz scores [9], with the pediatric investigator (HCM) making the final determination. Whenever possible, gestational age was calculated from the first day of the mother's last menstrual period. Gestational ages were accepted only if calculated and estimated gestational ages were the same. Otherwise, infants were classified only as pre-term or full-term infants. The diagnosis of pre-term retardation in growth of fetal soft tissues (low ponderal index) and of growth in crown-heel length was made using the Kansas City fetal growth tables [8].

Mothers in families paying full hospital costs and physicians' fees were classified in socioeconomic group I if the mother had completed more than 12 years of school and in group II if she had completed 12 or fewer years of school. Mothers were placed in socioeconomic group III if their hospital and physician's charges were discounted or limited to third-party payments; both physicians' charges and hospital charges were greater than ordinarily would be reimbursed by third-party payors, and their forgiveness of these charges suggested limited financial resources. Mothers were assigned to socioeconomic group IV if the head of household was on welfare or unemployed.

RESULTS

There were 1,848 white mothers of singleton infants in this study, of whom 1,141 had high-risk factors and 707 were low-risk mothers. The 1,141 high-risk mothers included 21 mothers with fetal conditions in their pregnancies (category 2, Table 1), 267 mothers with medical or obstetric complications of pregnancy (category 3, Table 1), and 853 mothers with adverse maternal practices (category 4, Table 1). The 707 low-risk mothers had none of the risk factors in Table 1 during their pregnancies. PROM occurred in 34/707 (4.8 percent) of low-risk mothers; in 3/21 (14 percent) of mothers with fetal conditions; in 22/267 (8.2 percent) of mothers with medical or obstetric complications of pregnancy; and in 78/853 (9.1 percent) of mothers with adverse maternal practices. A total of 137 mothers had PROM.

Data in Table 2 provide information on frequencies of PROM and rates of LBW pre-term and full-term infants born to mothers with different types of risk factor in their pregnancies. The data show that PROM occurred earlier in the third trimester, and with greater frequency, in most categories of high-risk pregnancy, and that PROM occurred later in the third trimester, and with less frequency, in mothers with low-risk pregnancies and in pregnancies with only medical/metabolic complications. With minor exceptions, mothers with the risk factors shown in Table 1 had higher rates of pre-term infants, low birth weight infants (especially very low birth weight infants), and PROM.

Data in Table 3 provide information on the mean birth weights of full-term infants at successive weeks of gestation who were born to mothers in Table 2, grouped according to the types of risks in their pregnancies. Note that in comparable risk factor categories, the numbers are smaller in Table 3, because only those deliveries for which there was agreement between methods of determining gestational ages were used. These data show that in the various high-risk groups, except for medical/metabolic problems, the mean birth weights of full-term infants were reduced compared to those from low-risk pregnancies, whether or not there was PROM, although it was more marked if there was. This part suggests that there is a reduction in prenatal growth in
TABLE 2
Incidence of Low Birth Weight White Infants, Pre-Term and Full-Term, Born to Mothers of Different Risk Groups, with and without Spontaneous Premature Rupture of Membranes (PROM)

| Total No. of Mothers | Pre-Term Infants | Full-Term Infants |
|----------------------|------------------|------------------|
|                      | No.  | %    | No.  | %    | No.  | %    |
| <2,000 g             |      |      |      |      |      |      |
| 2,000–2,499 g        |      |      |      |      |      |      |
| 2,500+ g             |      |      |      |      |      |      |
| a. Low-Risk Mothers  |      |      |      |      |      |      |
| No PROM              | 673  | (95.2)| 1    | (0.1)| 8    | (1.2)| 4    | (0.5)| 660  | (98.1)|
| PROM                 | 34   | (4.8)| 0    | —   | 2    | (5.9)| 0    | —   | 32   | (94.1)|
| b. Mothers with Uterine/Placental Complications of Pregnancy\(a\) |      |      |      |      |      |      |
| No PROM              | 34   | (73.9)| 5    | (14.7)| 1    | (2.9)| 4    | (11.8)| 24   | (70.6)|
| PROM                 | 12   | (26.1)| 3    | (25.0)| 4    | (33.3)| 2    | (16.7)| 3    | (25.0)|
| c. Mothers with Medical/Metabolic Complications of Pregnancy\(b\) |      |      |      |      |      |      |
| No PROM              | 55   | (98.2)| 1    | (1.8)| 1    | (1.8)| 0    |      | 53   | (96.4)|
| PROM                 | 1    | (1.8)| 0    | —   | 0    | —   | 0    | 1    | 1    | (100.0)|
| d. Mothers with Medical/Metabolic Complications and Adverse Practices\(c\) |      |      |      |      |      |      |
| No PROM              | 66   | (90.4)| 3    | (4.6)| 2    | (3.0)| 5    | (7.6)| 56   | (84.8)|
| PROM                 | 7    | (9.6)| 0    | —   | 0    | —   | 0    | 7    | 7    | (100.0)|
| e. Mothers Who Smoked Throughout Pregnancy |      |      |      |      |      |      |
| No PROM              | 404  | (91.0)| 4    | (1.0)| 11   | (2.7)| 5    | (1.2)| 384  | (95.0)|
| PROM                 | 40   | (9.0)| 6    | (15.0)| 2    | (5.0)| 2    | (5.0)| 30   | (75.0)|
| f. Mothers with Multiple Adverse Practices |      |      |      |      |      |      |
| No PROM              | 183  | (89.7)| 1    | (0.5)| 5    | (2.7)| 10   | (5.5)| 167  | (91.3)|
| PROM                 | 21   | (10.3)| 5    | (23.8)| 2    | (9.5)| 2    | (9.5)| 12   | (57.1)|

\(a\)Uterine/placental complications of pregnancy in part b: infections \((n = 14)\), placenta abruptio \((n = 11)\), placenta accreta \((n = 5)\), baddledore placenta \((n = 4)\), polyhydramnios \((n = 4)\), bicorneuate uterus \((n = 3)\), multiple placental infarcts \((n = 4)\), uterine fibroids \((n = 1)\)

\(b\)Medical/metabolic complications of pregnancy in part c: pre-eclampsia \((n = 35)\), hypertension \((n = 7)\), diabetes mellitus \((n = 8)\), gestational diabetes \((n = 6)\)

\(c\)Medical/metabolic complications of pregnancy in part d: pre-eclampsia \((n = 37)\), hypertension \((n = 25)\), diabetes mellitus \((n = 2)\), gestational diabetes \((n = 9)\)

these groups, and we hypothesize that this growth reduction may play a role in the etiology of PROM.

**Low-Risk Pregnancies**

The frequency of PROM in low-risk pregnancies in Table 2 was low, 34/707 (4.8 percent). Second, the incidence of pre-term infants born to low-risk mothers with PROM was 2/34 (5.9 percent), which was low compared to the incidence of 22 pre-term infants among 81 high-risk mothers with PROM (27 percent), and the birth weights of these two were over 2,000 g; however, the incidence of pre-term infants born to low-risk mothers without PROM was even lower, 9/673 (1.3 percent). Note in Table 3 that the mean birth weights of full-term infants born to low-risk mothers with and without PROM were comparable and were among the highest in this study.
TABLE 3
Mean Weights (g) of White, Full-Term Infants Born to Mothers of Different Risk Groups, with and without PROM, by Gestational Age

| PROM Status                        | Total Infants No. | Gestational Age (Weeks)* |
|------------------------------------|-------------------|--------------------------|
|                                    | Average (No.)     | 37 | 38 | 39 | 40 | 41 | 42+ |
| a. Low-Risk Mothers                |                   |    |    |    |    |    |     |
| No PROM                            | 490               | 2,945 (27) | 3,286 (32) | 3,424 (99) | 3,545 (168) | 3,695 (111) | 3,652 (53) |
| PROM                               | 29                | 2,961 (4)  | 3,214 (4)  | 3,458 (9)  | 3,781 (8)  | 3,607 (3)  | 3,010 (1)  |
| b. Mothers with Uterine/Placental Complications of Pregnancy |                   |    |    |    |    |    |     |
| No PROM                            | 26                | 3,105 (1)  | 2,913 (3)  | 2,849 (5)  | 2,905 (6)  | 3,501 (3)  | 2,913 (8)  |
| PROM                               | 5                 | Mean of all ages = 2,700 |     |    |    |    |     |
| c. Mothers with Medical/Metabolic Complications of Pregnancy |                   |    |    |    |    |    |     |
| No PROM                            | 38                | 3,120 (7)  | 3,316 (6)  | 3,544 (11) | 3,748 (10) | 4,100 (4)  |     |
| PROM                               | 0                 |        |    |    |    |    |     |
| d. Mothers with Medical/Metabolic Complications and Adverse Practices |                   |    |    |    |    |    |     |
| No PROM                            | 51                | 2,736 (2)  | 3,043 (8)  | 3,250 (17) | 3,082 (14) | 3,847 (5)  | 3,139 (5)  |
| e. Mothers Who Smoked Throughout Pregnancy |                   |    |    |    |    |    |     |
| No PROM                            | 314               | 3,035 (13) | 3,073 (34) | 3,224 (64) | 3,352 (101) | 3,386 (70) | 3,596 (32) |
| Average no. cigarettes smoked PROM | 24                | 14           | 16           | 18           | 17           | 17           | 15           |
| Average no. cigarettes smoked      |                   | 15           | 27           | 15           | 12           | 17           | 23           |
| f. Mothers with Multiple Adverse Practices |                   |    |    |    |    |    |     |
| No PROM                            | 140               | 2,856 (15) | 2,838 (20) | 3,156 (30) | 3,242 (33) | 3,409 (30) | 3,414 (12) |
| PROM                               | 10                | 2,745 (3)  | 2,593 (1)  | 3,038 (3)  | 3,659 (3)  | —            | —            |

*These numbers are smaller than those in Table 2 because the dates of gestation could not be reconciled between methods; there was complete agreement on dates for those pregnancies shown in Table 3.

These infants were full-term but exact dates were uncertain.

In Tables 2 and 3, comparison of rates and birth weights for low- and high-risk mothers illustrates that in high-risk mothers: (1) the frequency of PROM was increased compared to that for low-risk mothers; (2) the occurrence of PROM before 37 weeks of pregnancy was increased in mothers with high-risk factors compared to low-risk mothers; and (3) the mean weights of full-term infants of mothers who smoked or had multiple adverse practices were lower than those from low-risk pregnancies, suggesting a degree of prenatal growth retardation. Also, the average birth weights by week of gestation were generally lower within a risk group for the infants of those mothers who had PROM compared to those who did not.

 Mothers with Uteroplacental Complications

The highest frequency of PROM, the highest incidence of pre-term infants, and the lowest mean birth weights of full-term infants occurred in a group of mothers with uteroplacental complications of pregnancy (part b of Tables 2 and 3). Among the 46 mothers with uteroplacental complications, 12 (26 percent) had PROM, and seven (58
percent) of these 12 mothers with PROM had pre-term infants under 2,500 g, the highest incidence in this study.

The incidence of pre-term infants born to 34 mothers with uterine/placental complications but no PROM was six (18 percent) compared to 7/12 (58 percent) among similar mothers with PROM (Fisher exact test, two-tailed: \( p = 0.021 \)). The mean birth weight of the five full-term infants born to mothers with uterine/placental complications and PROM was 2,700 g, which was below the mean birth weight of all the 26 full-term infants born to similar mothers with no PROM.

**Medical or Obstetrical Complications**

Mothers with medical or obstetric complications of pregnancy had the widest variations in the incidence of PROM, the time of pregnancy in which PROM occurred, incidences of pre-term births, and mean birth weights of full-term infants. Data in part c of Tables 2 and 3 show that mothers with medical/metabolic complications of pregnancy (pre-eclampsia, hypertension of more than a month's duration preceding delivery, diabetes mellitus, or gestational diabetes) had the lowest frequencies of PROM. There were 56 mothers who had a single medical/metabolic complication and no other known risk factors of the type in Table 1, of whom only one (2 percent) had PROM, and her infant was full-term. In the group of 55 mothers without PROM, there were two mothers (3.6 percent) who had pre-eclampsia and pre-term infants after induction of labor or Cesarean section without labor.

There were 73 mothers with medical-metabolic complications who also had other risk factors, usually adverse practices—mainly cigarette smoking; seven (9.6 percent) of these had PROM, but all seven of their infants were full-term (Table 2, part d). Five of the 66 mothers with metabolic conditions without PROM had pre-eclampsia and pre-term births (7.6 percent); only two of the five mothers of pre-term infants had spontaneous onsets of labor.

In Table 3, the mean birth weights of infants born to mothers with complications of pregnancy combined with other risks (part d) were usually below the mean birth weights of infants born to mothers with a single complication of pregnancy and no other risks. The mean birth weights of infants born to mothers with medical/metabolic complications (part c) were similar to or greater than the mean birth weights of infants born to low-risk mothers (part a).

**Smoking During Pregnancies**

Data in Table 2, part e, show that in the 444 mothers who reported smoking one to 60 cigarettes a day throughout pregnancy, but who had none of the other risks in Table 1, the frequency of PROM was 40/444 (9 percent), which was significantly higher than the frequency of 34/707 (4.8 percent) in low-risk pregnancies (\( X^2 = 8.0, p = 0.0047 \)). The incidence rate of pre-term infants born to smoking mothers who had PROM was 8/40 (20 percent), more than three times as high as the incidence rate of pre-term births in low-risk mothers with PROM, and five times as high as the incidence rate of pre-term infants born to smoking mothers who had no PROM, 15/404 (3.7 percent). It is important to note that in Table 3 the average number of cigarettes smoked per day was about the same among mothers with and without PROM and that the mean birth weights of full-term infants born to cigarette smokers was lower among mothers with PROM than among mothers who had no PROM (except at 38 weeks).
Multiple Adverse Practices

Part f of Tables 2 and 3 show data on mothers with multiple adverse maternal practices in their pregnancies and none of the other risks in Table 1. These data illustrate a greater increase in frequency of PROM, a higher incidence of pre-term infants, and a greater decrease in mean birth weight of full-term infants among mothers with PROM than were observed among mothers who had a single adverse practice: smoking cigarettes. It is interesting that among the 204 mothers with multiple adverse practices, 196 (96 percent) smoked cigarettes as one of their multiple adverse practices. The main additional practices were, in descending order, low weight gains, being underweight for height at conception (for definitions, refer to Table 1), and being under 17 or over 34 years of age at time of delivery. Abuse of alcohol or addicting drugs was limited to one mother who was on heroin and methadone.

The frequency of PROM among the 204 mothers with multiple adverse practices, as shown in part f of Table 2, was 21 (10.3 percent), twice the frequency of 34/707 (4.8 percent) in low-risk mothers. The incidence of pre-term births among the 21 mothers with PROM was seven (33 percent), compared to an incidence of 6/183 (3.3 percent) among mothers with multiple adverse practices but no PROM.

The mean birth weights of the 140 full-term infants born to mothers with multiple adverse practices but no PROM were substantially lower than the mean birth weights of full-term infants in Table 3 born to mothers who had a single adverse maternal practice, except at 41 weeks, at which time they were approximately the same.

Prenatal Growth Retardation

The types of prenatal growth retardation among full-term infants born to mothers with PROM are shown in Table 4. The two main types of prenatal growth retardation were fetal skeletal growth retardation (short crown-heel length for gestational age, sex, and race of infant) and fetal malnutrition (low ponderal index with a satisfactory crown-heel length for gestational age).

Neither of the two main types of growth retardation appeared among the 32 full-term infants born to low-risk mothers with PROM. As shown in Table 4, in the group of 78 full-term infants born to high-risk mothers with PROM there were 15 infants who at birth had fetal skeletal growth retardation, and there were five others who had low ponderal indices with birth weights below the fifth percentiles for their sex, gestational ages, and race. Two other infants had birth weights below the fifth percentiles, and their crown-heel lengths were below the tenth percentiles. Two infants had a small head circumference only. Altogether, in the group of 78 high-risk mothers with PROM there were 15 full-term infants with short crown-heel lengths, five others with low ponderal indices, and five others still with other evidence of prenatal growth retardation. The first group strongly suggests prenatal growth retardation beginning fairly early in pregnancy. The five infants with low ponderal indices and satisfactory crown-heel lengths for their gestational ages had growth retardation of soft tissues, probably only in late pregnancy. The overall difference in the incidence of prenatal growth retardation in full-term infants born to high- and low-risk mothers with PROM was great: 32 percent in the high-risk group vs. 6 percent in the low-risk group (p = .004).

The important question of whether or not skeletal and/or soft tissue growth retardation occurred prenatally in pre-term infants born to 673 low-risk mothers (n = 9) is more difficult to answer, because so few pre-term infants under 2,500 g were
TABLE 4
Types of Prenatal Growth Retardation in Full-Term Infants Born to High- and Low-Risk Mothers with Spontaneous Premature Rupture of Membranes (PROM)

| Measurements Below Fifth Percentiles<sup>a</sup> | High-Risk | Low-Risk |
|------------------------------------------------|-----------|----------|
|                                                   | n = 78    | n = 32   |
| Crown-heel lengths                                |           |          |
| Crown-heel lengths, low ponderal indices and birth weight | 4         | 0        |
| Crown-heel lengths and birth weight               | 8         | 0        |
| Crown-heel lengths only                           | 3         | 0        |
| Low ponderal indices and birth weight              | 5         | 0        |
| Birth weight only<sup>b</sup>                      | 2         | 0        |
| Birth weight and head circumference                | 1         | 2        |
| Head circumference only                            | 2         | 0        |
| Total<sup>c</sup>                                 | 25        | 2        |

<sup>a</sup>Based on Kansas City fetal growth tables [8]
<sup>b</sup>These two infants had crown-heel lengths and ponderal indices below the tenth percentiles.
<sup>c</sup>Chi-square overall proportion of growth retardation among high- vs. low-risk group mothers = 8.16 on one degree of freedom; p = 0.004.

born to them. Figure 1 shows the crown-heel lengths by week of gestation for pre-term births to low-risk mothers with no PROM and to two groups of high-risk mothers with PROM; this graph was done only for infants whose calculated and gestational ages were the same. In Fig. 2, a similar plot was done for the same three risk groups, except that none of the infants in Fig. 2 were from pregnancies with PROM. In Fig. 1, the crown-heel lengths for low-risk pre-term births appear to be higher than the average of the two high-risk groups. The same general pattern appears to hold in Fig. 2, where none of the infants were from pregnancies with PROM, but the differences between the groups appear less striking.

![Graph showing crown-heel lengths by week of gestation](image)

**FIG. 1.** Pre-term deliveries with PROM: Crown-heel length by week of gestation.
Table 5 shows that, within comparable risk groups, the frequency of PROM did not vary greatly between different socioeconomic (SES) levels of heads of households. It is interesting, however, that in both risk factor categories, PROM occurred more frequently in the upper two SES groups than in the two lower SES groups.

DISCUSSION

The analysis in this and one other paper [10] suggest that the causal pathway is twofold: (1) risk factors directly increase the incidence of low birth weight, and (2) risk factors increase the incidence of PROM, which, in turn, further increases the incidence of low birth weight. In the presence of other risk factors, PROM appeared to have serious consequences, possibly because it produced a premature delivery imposed on growth retardation. Data from Table 2 for low-risk pregnancies suggests, however, an absence of prenatal growth retardation in full-term infants born to low-risk mothers, whether or not PROM occurred, and the PROM did not appear to have serious consequences.

The present results do not determine the causes of PROM, but they do suggest an hypothesis: the conditions causing fetal growth retardation also impair the development of normal tensile strength of the amnion and chorion, which results in more premature rupture of these membranes. The data in this study suggest that an analysis of the strength and histochemical composition of fetal membranes of pregnancies with PROM and a control group without PROM might reveal important differences. The hypothesis is supported by the observation that the frequency of PROM was significantly increased among mothers of undergrown infants at birth compared to the frequency of PROM among mothers of newborn infants who attained adequate levels of growth. The frequency of PROM was not only increased significantly among mothers of undergrown newborn infants, but PROM also occurred much earlier in pregnancy in undergrown infants. The incidence of pre-term infants in the birth range...
TABLE 5
Effect of Socioeconomic Level of Heads of Household among Mothers with Low and High Frequencies of Spontaneous Premature Rupture of Membranes (PROM)

| Socioeconomic Group | Frequency of PROM |          |          |          |     |     |     |          |          |
|---------------------|------------------|---------|---------|---------|-----|-----|-----|---------|---------|
|                     | Total             | With PROM |         |         |     |     |     | Total   | With PROM |
|                     | No.               | No.     | %       | No.     | No. | %  | No. | No.     | %       |
| Group I              | 317               | 17      | 5.4     | 82      | 13  | 15.9|     |         |          |
| Group II             | 259               | 12      | 4.6     | 236     | 27  | 11.4|     |         |          |
| Group III            | 108               | 6       | 5.6     | 137     | 9   | 6.6 |     |         |          |
| Group IV             | 145               | 5       | 3.4     | 232     | 24  | 10.3|     |         |          |
| Total                | 829               | 40      | 4.8     | 687     | 73  | 10.6|     |         |          |

Tests of independence for frequency of PROM between different socioeconomic status (SES) groups:
- Low-Risk: Chi-square = 0.094; d.f. = 3; p = 0.81; Not significant
- High-Risk: Chi-square = 4.92; d.f. = 3; p = 0.178; Not significant

*Low-risk: Includes low-risk mothers and mothers with pre-eclampsia, hypertension, diabetes mellitus, and gestational diabetes
*High-risk: Includes high-risk groups shown in Table 2, except for parts a and f.

of under 2,500 g born to mothers with PROM was several times greater than the incidence of pre-term infants born to mothers with no PROM.

The tendency of pre-term infants born to mothers with PROM to have very low birth weights (under 2,000 g) was associated with the adverse practices adopted by mothers during the pregnancy, especially cigarette smoking. Thus, this study provides suggestive evidence that reducing adverse practices, especially smoking, may reduce the incidence of PROM, and, if PROM still occurs, the incidence of small pre-term infants would probably be lower.

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REFERENCES

1. Guidelines for Perinatal Care, second edition. American Academy of Pediatrics and American College of Obstetrics and Gynecologists, 1988
2. Oxorn H: Human Labor and Birth. Norwalk, CT, Appleton-Century-Crofts, 1988
3. Cooperstock M, England JE, Wolfe RA: Circadian incidence of premature rupture of the membranes in term and preterm births. Am J Obstet Gynecol 69:936–941, 1980
4. Meyer MD, Tonascia JA: Maternal smoking, pregnancy complications and perinatal mortality. Am J Obstet Gynecol 128:494–502, 1977
5. Miller HC, Jekel JF: The effect of race on the incidence of low birth weight: Persistence of effect after controlling for socioeconomic, educational, marital, and risk status. Yale J Biol Med 60:221–232, 1987
6. Miller HC, Jekel JF: Incidence of low birth weight infants born to mothers with multiple risk factors. Yale J Biol Med 60:397–404, 1987
7. Miller HC, Jekel JF: The epidemiology of white full-term infants with short crown-heel lengths for gestational ages at birth. Yale J Biol Med 62:1–12, 1989
8. Miller HC: Intrauterine growth retardation: An unmet challenge. Am J Dis Child 135:944–948, 1981
9. Dubowitz LMS, Dubowitz V, Goldberg C: Clinical assessment of gestational age in newborn infants. J Pediat 77:1–10, 1970
10. Jekel JF, Miller HC: Epidemiology of spontaneous premature rupture of membranes. Submitted for publication