
Michael D. Kogan, PhD
Greg R. Alexander, MPH, ScD
Milton Kotelchuck, PhD, MPH
Marian F. MacDorman, PhD
Pierre Buekens, MD
Joyce A. Martin, MPH
Emile Papiernik, MD

National statistics indicate that the rates of both preterm birth and low-birth-weight (LBW) infants have increased in the last 10 to 15 years. Since infants born with these conditions are at greatly increased risk of infant mortality and subsequent developmental difficulties, the rising incidence of these adverse birth outcomes is a matter of importance.

During this same period, there has been a steady expansion in the percentage of women with adequate prenatal care utilization, as defined by the standards recommended by the American College of Obstetricians and Gynecologists, as well as intensive prenatal care utilization, defined as women receiving more than the recommended number of visits. Early and adequate utilization of prenatal care has been associated with a number of benefits, including more adequate immunizations and well-child care for the infant, and possibly with a decrease in LBW infants and infant mortality. However, the purported benefits of prenatal care have increasingly been questioned.

The parallel rise in the preterm birth rate and the proportion of women with intensive prenatal care utilization has led some researchers to suggest that the benefits of prenatal care have been overestimated, and infant mortality have been questioned. Other researchers have suggested that the increasing preterm birth rate may be due to a number of factors, including an increase in multiple births, more aggressive management of high-risk pregnancies, and an increased use of ultrasonography to measure fetal growth.

Context Multiple births account for an increasing percentage of all low-birth-weight infants, preterm births, and infant mortality in the United States. Since 1981, the percentage of women with multiple births who received intensive prenatal care (defined as a high number of visits, exceeding the recommendation of the American College of Obstetricians and Gynecologists by approximately 1 SD beyond the mean number of visits for women initiating care within each trimester) has increased significantly.

Objectives To explore the hypothesis that more aggressive management of twin-birth pregnancies may be associated with changes in birth outcomes in this population.

Design, Setting, and Subjects Cross-sectional and trend analysis of data from the National Center for Health Statistics' birth and infant death records for all twin births occurring in the United States between 1981 and 1997, excluding those with missing or inconsistent data.

Main Outcome Measures Trends in preterm birth, low birth weight, preterm and term small-for-gestational-age (SGA) births, and infant mortality, by level of prenatal care utilization.

Results The preterm birth rate for twins increased from 40.9% in 1981 to 55.0% in 1997. The percentage of low-birth-weight infants increased from 51.0% to 54.0%. The preterm SGA rate also increased from 11.9% to 14.1%, while the term SGA rate decreased from 30.7% to 20.5%. For women with intensive prenatal care utilization, the preterm birth rate increased from 35.1% to 55.8%, compared with an increase from 50.6% to 59.2% among women with only adequate use. Twin preterm deliveries involving either induction or first cesarean delivery also increased from 21.9% to 27.3% between 1989-1991 and 1995-1997. The twin infant mortality rate for women with intensive prenatal care use declined between 1983 and 1996 and remained lower than the overall twin infant mortality rate.

Conclusions An apparent increase in medical interventions in the management of twins may result in the seeming incongruity of more prenatal care and more preterm births; however, these data suggest that women with intensive prenatal care utilization also have a lower infant mortality rate.

JAMA. 2000;283:335-341
www.jama.com

©2000 American Medical Association. All rights reserved.
singleton births. It was suggested that among multiple births compared with national data indicated that the pre-
deaths in 1997. Moreover, the incidence of multiple births had intensive prenatal care utilization compared with 22.8% by 1995 for this subgroup. Among women with singleton births, 3.3% had intensive prenatal care utilization in 1981 compared with 6.3% in 1995.

While constituting only 3% of births in the United States in 1997, multiple births are a high-risk group, which accounted for 21% of all LBW births, 14% of preterm births, and 13% of infant deaths in 1997. Moreover, the incidence of multiple births has increased notably. From 1980-1997, the number of twin births increased 52%, while the number of higher-order multiple births increased 404%. Recent research based on Canadian national data indicated that the preterm birth rate has risen much faster among multiple births compared with singleton births. It was suggested that obstetric interventions were changing the upper tail of gestational age distributions among multiple births, although this relationship has not been explored more directly.

Our goals in this article are to (1) present trends in birth outcomes for twins in the United States; and (2) explore the hypothesis that more aggressive management of multiple pregnancies, as suggested by intensive prenatal care utilization and induction of labor and first cesarean deliveries, may be associated with changes in birth outcomes in this high-risk subgroup.

METHODS

Two different data sources were used. The National Center for Health Statistics natality files from 1981-1997 were used for all analyses, except for infant mortality, which used the National Center for Health Statistics–linked birth-infant death cohorts for 1983-1984, 1989-1990, and 1995-1996. The analysis is limited to twin births, as they constitute the large majority of multiple births. There were 1479862 twin births over this 17-year period.

Records with inconsistent or missing values for the month prenatal care began, the number of prenatal visits, or the length of gestation were excluded from the analysis. Records with 1 or more missing values for gestational age, the month care began, or number of visits ranged from 5.0% to 6.8% for each year.

Gestational age in completed weeks is computed from the interval between the first day of the LMP and the date of birth. Records missing the date of the LMP are imputed when there is a valid month and year. From 1989-1997, clinical estimate of gestation was used in the computation of gestational age in cases where the date of the LMP was not reported or where the LMP date was inconsistent with the birth weight. Inconsistency and imputation procedures have been described in detail elsewhere. Approximately 4% to 5% of the gestational ages during the period were based on clinical estimate of gestation.

While recent research indicated that intensive prenatal care utilization increased notably among multiple births according to both the R-GINDEX and the Adequacy of Prenatal Care Utilization Index, we chose to use the R-GINDEX based on the recommendation that the R-GINDEX was useful for research focusing on birth outcomes and to simplify the article by limiting the number of indices revealing similar patterns. The R-GINDEX is based on calculations of when a woman began care and the number of visits she received, and is adjusted for the length of gestation at delivery. It is derived from the American College of Obstetricians and Gynecologists recommendations for prenatal care. A woman’s utilization of prenatal care can be classified as “intensive,” “adequate,” “intermediate,” “inadequate,” “no care,” or “missing.” The intensive utilization category of the R-GINDEX reflects women who had an excessively large number of prenatal care visits (approximately 1 SD beyond the mean number of visits) given their gestational age at delivery and the trimester that prenatal care began. For example, a woman who starts care in the first trimester, delivers at 39 weeks’ gestation, and receives 17 or more prenatal care visits would be defined as exhibiting intensive prenatal care utilization. The American College of Obstetricians and Gynecologists recommendation for adequate prenatal care utilization for this case would be 12 visits. Detailed descriptions of the R-GINDEX and the algorithm used to calculate the index are available elsewhere.

We examined 5 outcome measures: trends in preterm birth, LBW, preterm small for gestational age (SGA), term SGA, and infant mortality. Preterm birth was defined as delivery from 20 to 36 weeks of gestation. Although twins have a different fetal growth pattern than singletons, we chose to use the same definition for preterm as have others examining preterm birth among twins for purposes of comparability. Low birth weight was defined as infants weighing less than 2500 g. Infants were classified as SGA using the 10th percentile of birth weight values of a previously reported 1991 US birth weight for gestational age reference curve and were categorized as preterm SGA or term (≥37 weeks gestation) SGA. Infant mortality was defined as a death before the first completed year of life. We chose to use infant rather than neonatal mortality since an increasing proportion of neonatal deaths are being postponed until the postneonatal period with advances in neonatal intensive care, and because a significant proportion of postneonatal deaths are related to perinatal causes. The findings of the study are essentially the same if neonatal mortality is used.

ANALYSIS

We present trends in preterm birth, LBW, preterm SGA, and term SGA for US twin births from 1981-1997. The per-
To examine whether more prenatal care may have altered birth outcomes, we explore the trends from 1981-1997 for preterm birth, preterm SGA, and term SGA comparing women with intensive prenatal care utilization with adequate and less than adequate (intermediate, inadequate, and no care) utilizers. Low birth weight was not included in further analyses because it may be reflective of either preterm birth or intrauterine growth retardation. Beginning in 1989, obstetric procedures were added to the natality files. We explore the trends in preterm birth among twins who were delivered with induction of labor or first cesarean deliveries by utilization level from 1989-1997.

We then compare the odds of delivering preterm in 1997 and 1990 with 1981, as a marker of more aggressive prenatal care, using multiple logistic regression within 3 models of prenatal care utilization. The first model was limited to women delivering twins and who had intensive utilization in either 1981, 1990, and 1997; the second was limited to women with adequate utilization in those years; and the third was limited to women with less than adequate utilization. The parameters in the logistic model were estimated by the maximum likelihood method. Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were calculated from the logistic analyses.

Last, we explore the changes in infant mortality rates (IMRs) among twin births in 1983-1984, 1989-1990, and 1995-1996 using the linked birth-infant death files stratified by level of prenatal care utilization, within the gestational age categories of less than 32, 32 to 36, and 37 or more weeks. Confidence intervals for IMRs were calculated based on a Poisson probability distribution, and z tests were used to compare the differences between the total IMR and each level of prenatal care utilization during each time period.

RESULTS

Table 1 indicates that there were notably different trends for preterm birth and LBW among twin births in the United States from 1981 to 1997. The preterm rate for twins increased markedly from 40.9% to 55.0%, while the LBW rate displayed lesser change; 51.0% in 1981 to 54.0% in 1997. Preterm SGA births increased from 11.9% to 14.1%, while the proportion of term SGA births decreased from 30.7% to 20.5%. The twin IMR also declined 44.4% from 1983 to 1996. Moreover, Table 1 indicates that twins are accounting for an ever-increasing percentage of all preterm and LBW births in the United States.

During the same period, the percentage of women who delivered twins and who had intensive utilization increased dramatically from 8.3% in 1981 to 22.7% in 1997. The percentage of...
women who delivered twins and who had adequate utilization increased from 47.8% to 55.7%. The percentage of women who delivered twins and who had less than adequate utilization declined steeply from 43.9% in 1981 to 21.6% (data available on request).

The Figure shows that the increase in the twin preterm birth rate per 100 twin births was conspicuously sharper among women who had intensive prenatal care utilization: from 35.1 in 1981 to 55.8 in 1997, an increase of 59%, although the rate for adequate utilizers remained higher. The preterm SGA rate also rose most sharply among intensive utilizers: from 8.7 in 1981 to 14.0 in 1997. The rate rose only from 13.4 to 14.6 among adequate utilizers, and from 10.9 to 12.4 among less than adequate utilizers. Term SGA exhibited a very different pattern, decreasing from a rate of 28.9 in 1981 to 19.1 in 1997 among women with intensive utilization; from 22.0 to 17.0 among adequate utilizers; and from 40.5 to 31.9 among less than adequate utilizers (data available on request).

Exploring the change in preterm birth among intensive utilizers further, we found that the increase was primarily for births between 32 and 36 weeks’ gestation. The rate rose from 26.8 in 1981 to 46.2 in 1997, or an increase of 72.4%. The rate for preterm birth less than 32 weeks’ gestation rose 16%; from 8.3 per 100 in 1981 to 9.6 per 100 in 1997.

We then explored the association between other obstetric procedures and twin preterm birth. Combining 3 years of data for statistical stability, we found that both the number and percentage of births delivered preterm with induction of labor or first cesarean delivery increased from 21.9 in 1989-1991 to 27.3 in 1995-1997 (Table 2), while the percentage of twin births delivered preterm without these procedures essentially remained the same at 25%. Among intensive utilizers, the percentage of twin births delivered preterm with induction or first cesarean delivery increased from 23.2% to 29.7% during this period, while the percentage of twin births delivered term or postterm declined from 54.0% to 46.2%.

After using multiple logistic regression to control for other factors, Table 3 indicates that the ORs for preterm twin birth increased for all women who delivered twins in 1997 compared with 1981. However, the largest increase occurred among women with intensive prenatal care utilization in 1997 compared with women who had the same level of prenatal utilization in 1981 (OR=2.29; 95% CI=2.13-2.44). Women who had less than intensive utilization were only about 45% more likely to deliver preterm in 1997 compared with 1981.

An analysis of IMRs among twin births by level of prenatal care utilization and gestational age in 1983-1984, 1989-1990, and 1995-1996 indicated significant declines in twin infant mortality among intensive utilizers who delivered preterm (Table 4), paralleling those across other utilization levels. During each period examined, both the preterm and overall twin IMR among intensive utilizers was significantly lower than the twin IMR among all twins. Further, the twin IMR for preterm births less than 32 weeks for intensive utilizers was significantly lower compared with other levels of utilization. For adequate utilizers, the term IMR was significantly lower than the overall twin IMR.

**COMMENT**

This study documents a notable increase in preterm births and preterm SGA among twin births in the United States from 1981 to 1997. This increase has not been distributed equally across levels of prenatal care utilization. Indeed, the rise in the twin preterm birth and preterm SGA rates has been much steeper among women who had intensive utilization. The preterm birth rate increase among the intensive utilizers occurred almost entirely among deliveries of 32 to 36 weeks’ gestation. At the same time, we observed a noteworthy decrease in term SGA births and in the twin IMR.

**Table 2.** Percentage of Twin Births Delivered Preterm (<37 Weeks) With Induction of Labor or First Cesarean Delivery by Level of Prenatal Care Utilization, 1989-1991 to 1995-1997

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensive</td>
<td>2.5 (211)</td>
<td>4.0 (216)</td>
<td>5.6 (345)</td>
</tr>
<tr>
<td>Adequate</td>
<td>1.4 (122)</td>
<td>2.2 (164)</td>
<td>2.7 (173)</td>
</tr>
<tr>
<td>Less than adequate</td>
<td>2.0 (5159)</td>
<td>3.2 (8678)</td>
<td>4.7 (1294)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1992-1994</td>
<td>22.9 (11128)</td>
<td>23.7 (12946)</td>
<td>24.1 (14899)</td>
</tr>
<tr>
<td>1995-1997</td>
<td>28.4 (36881)</td>
<td>28.3 (40307)</td>
<td>27.9 (42833)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1989-1991</td>
<td>29.9 (33887)</td>
<td>33.8 (37888)</td>
<td>37.9 (38888)</td>
</tr>
<tr>
<td>1995-1997</td>
<td>62.1 (51351)</td>
<td>59.9 (44518)</td>
<td>60.1 (38098)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1989-1991</td>
<td>46.5 (64477)</td>
<td>44.5 (63329)</td>
<td>42.3 (64902)</td>
</tr>
<tr>
<td>1992-1994</td>
<td>25.3 (66127)</td>
<td>25.7 (69836)</td>
<td>25.5 (71096)</td>
</tr>
<tr>
<td>1995-1997</td>
<td>52.8 (136085)</td>
<td>49.6 (134868)</td>
<td>47.2 (131489)</td>
</tr>
</tbody>
</table>

©2000 American Medical Association. All rights reserved.
Collectively, these observed trends in preterm births, preterm SGA, and term SGA indicate that twin births are increasingly less likely to be delivered at term. We believe that changes in obstetric practice and interventions may be partly responsible for this change. This interpretation is supported by the greater increases in preterm birth rates among women with intensive utilization. Previous research has suggested that the maturation process of plural births is accelerated in comparison with that of singleton births, although opposing findings exist. As the optimal intraterine growth and lowest morbidity may occur earlier for twins than for singletons, the traditional wisdom of maintaining a pregnancy to "term," ie, until 37 weeks' gestation, may not be equally applicable to twin births due to the increasing morbidity and mortality associated with postmaturity that may occur much earlier in twins. As the optimal intraterine growth and lowest morbidity may occur earlier for twins than for singletons, the traditional wisdom of maintaining a pregnancy to "term," ie, until 37 weeks' gestation, may not be equally applicable to twin births due to the increasing morbidity and mortality associated with postmaturity that may occur much earlier in twins. As the optimal intraterine growth and lowest morbidity may occur earlier for twins than for singletons, the traditional wisdom of maintaining a pregnancy to "term," ie, until 37 weeks' gestation, may not be equally applicable to twin births due to the increasing morbidity and mortality associated with postmaturity that may occur much earlier in twins. As the optimal intraterine growth and lowest morbidity may occur earlier for twins than for singletons, the traditional wisdom of maintaining a pregnancy to "term," ie, until 37 weeks' gestation, may not be equally applicable to twin births due to the increasing morbidity and mortality associated with postmaturity that may occur much earlier in twins.

Changes in methods of gestational age dating over time might also have affected the results, wherein the entire gestational age distribution shifted slightly to the left. If true, it might account for the increasing twin preterm rate, the decreasing term SGA rate, and the smaller increase in LBW rate. However, there are a number of factors that argue against this theory. The rise in the singleton preterm birth rate has not been nearly as steep as for twins. There was not a uni-

### Table 4. Infant Mortality Rates (IMRs) per 1000 Live Births Among US Twins by Level of Prenatal Care Utilization and Gestational Age: 1983-1984, 1989-1990, and 1995-1996

<table>
<thead>
<tr>
<th>Gestational age, wk</th>
<th>Intensive</th>
<th>Adequate</th>
<th>Less Than Adequate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;32</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983-1984</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1989-1990</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995-1996</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥37</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall IMR</td>
<td>27.6 (24.6-30.5)</td>
<td>53.8 (51.9-55.6)</td>
<td>51.0 (48.9-53.1)</td>
<td>50.0 (48.7-51.3)</td>
</tr>
<tr>
<td>No. of deaths</td>
<td>343</td>
<td>3201</td>
<td>2433</td>
<td>5977</td>
</tr>
<tr>
<td>1989-1990</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995-1996</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall IMR</td>
<td>22.1 (20.5-23.7)</td>
<td>43.4 (42.0-44.8)</td>
<td>48.5 (46.6-50.4)</td>
<td>41.1 (40.1-42.1)</td>
</tr>
<tr>
<td>No. of deaths</td>
<td>713</td>
<td>3735</td>
<td>2721</td>
<td>7169</td>
</tr>
</tbody>
</table>

*Data are presented as IMR (95% confidence interval) unless otherwise indicated.
†California and New Mexico not included for 1983-1984.
‡Significant difference based on the z test for comparison of IMRs. Comparison was between the total IMR for that period and gestational age strata, and the level of prenatal care utilization for the same period and gestational age strata. For example, in 1983-1984, the IMR for women receiving intensive prenatal care and delivering before 32 weeks (IMR = 194.4) was significantly different than the total IMR for women delivering twins before 32 weeks (IMR = 287.4).
form shift in the gestational age distribution. Almost the entire change occurred among twins of 32 to 36 weeks' gestation, with the largest change occurring at 35 to 36 weeks, when the median birth weights for twins are 2353 and 2500 g, respectively. 21 Moreover, the increase in preterm birth occurred only among twins delivered with the assistance of obstetric procedures such as induction of labor or first cesarean delivery. Finally, the vast majority (about 95%-96%) of gestational age calculations are based on LMP throughout the study period. The data from 1990 to 1997 were examined excluding clinical estimate of gestation, and the results were essentially the same (data available on request).

In addition to potential innovations in obstetric practice, a number of other factors may also be affecting both the incidence and outcomes of twin births. Changes in sociodemographic characteristics of the population, eg, the increasing percentage of births to older mothers, may play a role. Fertility therapies have been indicated as markedly contributing to the rise in multiple births and in preterm and LBW births in the United States and elsewhere. 37,38 In the early 1990s, approximately 2.4% of twin infants were conceived through assisted-reproductive technologies. 37 No national estimates exist on the contribution of ovulation-stimulation drugs without the use of assisted-reproductive technologies to twin births, although data from the East Flanders, Belgium Prospective Twin Survey indicated that 14% of twin births were associated with use of fertility-enhancing drugs. 39 There are conflicting reports regarding whether twin births conceived through assisted-reproductive technologies are more fragile and at greater risk of perinatal mortality or preterm delivery. 40,41

There are potential limitations to this study. Intensive utilization refers only to the number of visits based on the initiation of care; it does not refer to the content of prenatal care. The accuracy and completeness of reporting on vital records are also possible limitations. It was unknown whether the first cesarean delivery was an elective obstetric procedure. There was also incomplete information on potential confounders, such as pregnancy complications like sexually transmitted diseases, which could lead to both an increase in utilization and independently to preterm birth. Research has indicated that reporting of gestational age on the birth certificate may be less accurate for preterm births, which can introduce measurement error and affect the accurate classification of preterm birth and prenatal care use. 42,43 However, recent research has indicated that improbable gestational ages for the recorded birth weights were considerably less for preterm twin births. 44 Also, this was not a matched set of twins, so disparities in twin pairs could not be examined.

We did not have accurate data on twin fetal mortality. An examination of twin fetal mortality ratios for 20 or more weeks' gestation over the study period indicated that they declined from 31.2 to 20.7 twin fetal deaths per 1000 live twin births (data available on request). However, a more detailed analysis of fetal mortality data by prenatal care utilization was not possible because a significant portion were missing information on prenatal care utilization. Nonetheless, the reduction in the fetal mortality ratio is important if the hypothesis is to be accepted that the increase in the preterm delivery rate may result from obstetric interventions. It also suggests that a shift from infant to fetal mortality does not account for the observed changes. Further research is needed on this topic.

Changes in reporting areas could have affected the results, 22 but our analyses did not reveal this. Two states did not collect information on the number of prenatal visits during the earlier part of the study period and were excluded from the analysis for those years. For the years 1989-1997, we examined the data both including and excluding these states and found negligible differences. Therefore, we included all states for 1989-1997 (data available on request).

Studies that have examined the relationship between prenatal care utilization and preterm birth or LBW have commonly begun with the hypothesis that receiving the recommended levels of prenatal care or more would reduce these adverse birth outcomes. 13 This study suggests that for the population of multiple births, increasing levels of prenatal care use may occur during periods of increasing preterm and LBW rates, while simultaneously exhibiting a decrease in IMRs. This research indicates that the relationship between prenatal care and birth outcomes may be far more complex, particularly when infant mortality is examined as well.

The declines in infant mortality among twin births in the United States may largely reflect the same technological and medical advances in high-risk obstetric and neonatal intensive care that have dramatically reduced birth weight and gestational age–specific neonatal mortality in the United States since the 1970s, including the increased use of corticosteroids. 45-47 However, the continuing increase in multiple and preterm births and their better survival rates has potential adverse consequences. While most of these preterm twins will be without marked problems, a small but growing number may have both short- and long-term disabilities and developmental delays. 48-50 The increasing number of surviving infants with disabilities that extend into their childhood and adult years has cost implications related to the ongoing provision of a wide array of health care, educational, and support services, as well as significant human costs in meeting the special needs of these children.

Twin births are accounting for a greater percentage of all LBW and preterm births in the United States, during a period when the overall rates for these outcomes and prenatal care have been increasing. This study may help us understand some of the seeming incongruity. More aggressive and more successful management of twin pregnancies may be accounting for part of the elevation in the preterm rate. To the extent that earlier deliveries of twins may result in reducing the risk of a fetal or infant death, the importance of early and ongoing utilization of prenatal care continues to be emphasized.
REFERENCES