Cesarean Delivery, Labor Induction, Prematurity and Neonatal Morbidity: New Jersey, 1997-2005

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June 25, 2010

Background

   Premature birth is a leading contributor to neonatal morbidity and mortality. Prematurity accounts for about one-third of all infant deaths and is associated with ten times higher medical costs in the first year of life. Health and developmental problems that have been associated with prematurity include respiratory distress, lung and heart complications, hemorrhage, immunological deficiencies, jaundice, anemia, and vision and hearing loss. Although the causes of premature birth are multiple and not completely understood, a number of risk factors, such as poor maternal health, smoking, infections and outcomes of past pregnancies, have been implicated and suggest a variety of modes for clinical intervention.

   The health problems associated with prematurity are often a function of the duration of gestation, and several standards for defining prematurity are used. The normal gestation time for a human infant is 39-40 completed weeks; traditionally an infant born after at least 37 completed weeks is considered full term. Yet birth even in the 37-38 week interval can bring about serious complications. A further difficulty for research and clinical practice is that not all pregnancies are accurately dated, so that gestational duration (or "gestational age") cannot be calculated with certainty.

   In the past decade New Jersey has seen dramatic increases in the utilization of two procedures—artificial induction of labor and planned cesarean delivery— which have had the effect of shortening gestation times. This trend has generated considerable debate about the appropriate use of these procedures, and the extent to which individual cases of such early deliveries are medically necessary is not clear. The American College of Obstetrics and Gynecology (ACOG) recommends that *elective* deliveries by induction or cesarean not be conducted before 39 completed weeks of gestation. Gestational age is to be determined by a first-trimester ultrasound, which is more reliable than calculation from the last menstrual period. When deliveries before 39 weeks are not elective but medically indicated, steps to ensure adequate fetal lung development should be implemented as early as possible.

The purely elective use of induction and/or cesarean is difficult to define and document. We can, however, approximately identify a population of births where the degree of medical necessity is low. In these births, delivery interventions are more likely to be elective, discretionary or the result of ineffective labor management. This approach allows us to describe trends that are the result of other than medical factors, and may be exposing mothers and newborns to unnecessary risks. This report explores changes in the distribution of gestational age at delivery for such a population of low-risk newborns in New Jersey during the period 1997-2005. We especially focus on the roles of artificial induction of labor and cesarean delivery. Our primary goal is to examine evolving obstetric practice and document the compliance of that practice with ACOG guidelines.

This report is one in a series of studies on changing utilization of cesarean delivery and its consequences for maternal and infant health. Previous studies are published at:
http://nj.gov/health/fhs/professional/mchepi.shtml.

Methods

Electronic Birth Certificate (EBC) files were linked to hospital discharge records for all deliveries at New Jersey hospitals, and for readmissions to New Jersey hospitals up to 60 days postpartum. Probabilistic linkage, using algorithms to indentify high-quality matches between files, was performed using AutoMatch. Records for 967,139 deliveries in New Jersey hospitals from 1997 to 2005 were available for analysis. Multiple gestation, gestational age, malpresentation, parity and history of prior cesarean are taken from the birth certificate record. New Jersey is unique in the availability of a direct measure of trial of labor for cesarean deliveries, validated by recording of the length of labor.

We focus most of our analyses on deliveries at low antepartum (pre-delivery) risk of complication. There were 770,063 singleton, deliveries with cephalic presentation and no prior cesarean (80% of all). We excluded deliveries with serious antepartum bleeding, severe hypertension, preeclampsia/eclampsia or uterine tissue abnormality, as they would be strong indications for obstetric intervention. These latter items are taken from the hospital discharge record.

Two other indications for early delivery are intrauterine growth restriction and macrosomia. These are measured in our data by statistical birthweight standards derived from all U.S. births in 1999 and 2000. Small for gestational age (SGA) is defined as birthweight below the 10th percentile for all deliveries at that gestational age; large for gestational age (LGA) is defined as birthweight above the 90th percentile. Applying all these criteria, about 60% of all deliveries were counted as at low antepartum risk for cesarean delivery or indicated induction of labor, leaving 587,835 deliveries for analysis.

Gestational age refers, by convention, to the number of completed weeks of the pregnancy. This means that a fetus "at 37 weeks" has already completed 37 weeks of gestation. Accurate calculation of the date of conception and gestational age must be done using measurements taken during a first-trimester ultrasound, and is called the *clinical estimate*. Calculation from the date of last menstrual period is often incorrect by several weeks. The New Jersey birth certificate reports the clinical estimate for gestational age.

The main focus of this report is on the utilization, scheduling and consequences of interventions that initiate delivery. The analyses presented here distinguish three circumstances of labor: spontaneous labor, artificial induction of labor, and cesarean delivery without a trial of labor. Induction of labor includes any medical or surgical method that initiates uterine contractions and/or cervical effacement (e.g., oxitocin, ripening agents, or amniotomy). Among the consequences of labor induction is a heightened risk of cesarean delivery (compared to spontaneous onset of labor).

The analysis incorporates gestational age in two distinct ways. When the incidence of one or more medical conditions is analyzed, gestational age is treated as an independent variable. Age-specific risks are calculated only for mothers and infants born at that exact number of completed weeks of gestation (often called *age-stratification*). For the incidence of artificial induction of labor and cesarean delivery, however, gestational age is a *dependent variable*, determined by medical intervention. Therefore we use a statistical approach for analyzing the age-specific risk of delivery more common in life-table and *survivor analysis*. The difference is that the population considered at risk for either labor induction or cesarean

delivery at 37 weeks gestation, for example, comprises all infants born that week *or later*. Those not delivered by *any* method at 37 weeks are then considered to be at risk at 38 weeks, and so on. This age-specific risk of delivery for each method is statistically independent of the fraction born at each gestational age, although in practice the risk-by-age curves have many similarities.

We analyze two specific neonatal outcomes that are frequently associated with prematurity: respiratory difficulties (respiratory distress syndrome and/or transient tachypnea) and hyperbilirubinemia. We include these as events only when they are confirmed by a relevant medical intervention: CPAP or mechanical ventilation in the first case and phototherapy in the second. These diagnoses and procedures are taken from the infant's hospital discharge record using ICD-9 coding. We also examine a general marker of neonatal morbidity, admission to the delivery hospital's neonatal intensive care unit (NICU) for two or more overnights, or transfer to a NICU at another facility for any duration.

These neonatal outcomes are analyzed by age-stratification. Age-specific incidence is also differentiated by the circumstance of labor, which is somewhat less typical than analysis by the ultimate route of delivery. This strategy is based on our overarching concern with the appropriate use and timing of labor induction. To develop a proper understanding of the risks, we need to consider both the heightened risk of cesarean and risks associated with delivery before spontaneous onset of labor. Since the most discretion regarding labor induction occurs in the period just before an infant is "full term," we focus most analysis on *near term* deliveries— *late preterm* deliveries, 34-36 weeks, and *early term* deliveries, 37-38 weeks.

Birth certificate files capture all births for the analysis period. Therefore we forego statistical inferences predicated on sampling variability. The public health significance of trend magnitudes and subgroup differences are and should be judged on clinical and public policy criteria.

Findings

Indicated Deliveries

Figure 1 displays the incidence of all cesarean deliveries without a trial of labor from 1997 to 2005, by gestational age and the status of various risk indicators. Deliveries predominantly occurred in weeks 38 through 40. Roughly half of all deliveries, about 14,000 in all, were associated with one or more risk factors— serious antepartum bleeding, severe hypertension, preeclampsia/eclampsia and uterine tissue abnormality, SGA or LGA. One clear trend is that the longer the gestation, the less likely the delivery was associated with these indications. At week 38 and all later weeks of completed gestation, more than half of all cesarean deliveries are to women without any of the indications we list.

Figure 2 displays the same analysis for induction of labor. In this graph, a much smaller proportion of interventions are for our major indications. Roughly 46,000 inductions were associated with our major indications, versus about 124,000 that were not. As with no-trial cesareans, the proportion of inductions performed for major indications decreased with gestational age. At 38 weeks the proportion was 30%, and at 41 weeks, 21%. The remainder of this report focuses on the population of "low-risk" deliveries, excluding the indications described here.

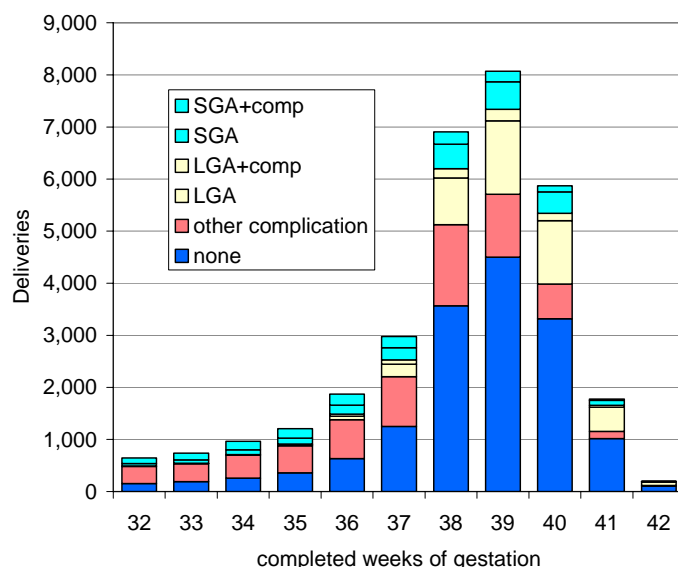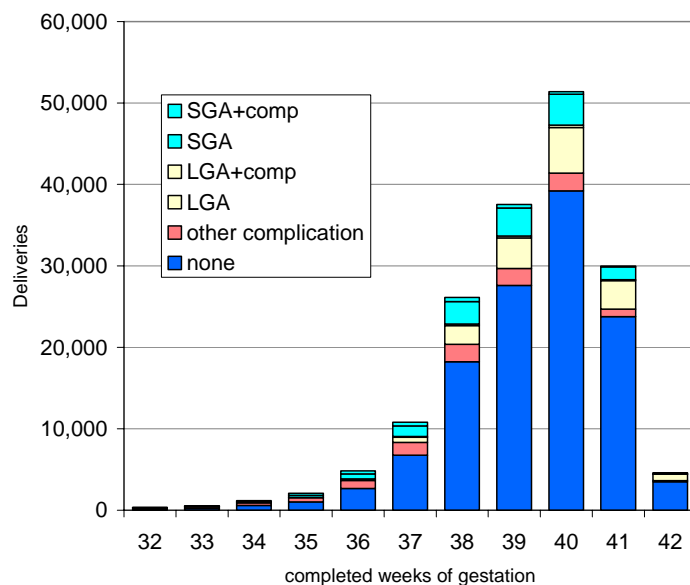Figure 1. Primary Cesarean Without Trial of Labor, 1997-2005

Figure 2. Artificial Induction of Labor, 1997-2005

Cesarean Deliveries to Low Risk Mothers

Figure 3 displays the risk of cesarean delivery for low-risk nulliparas (first-time mothers) as the pregnancy progresses. The horizontal axis marks each passing week of gestation, representing all infants delivered that week or later. The age-specific risk of delivery by cesarean rose steadily from 35 weeks onward, with generally higher levels of risk during each successive time period. For example, cesarean rates among this population of women were:

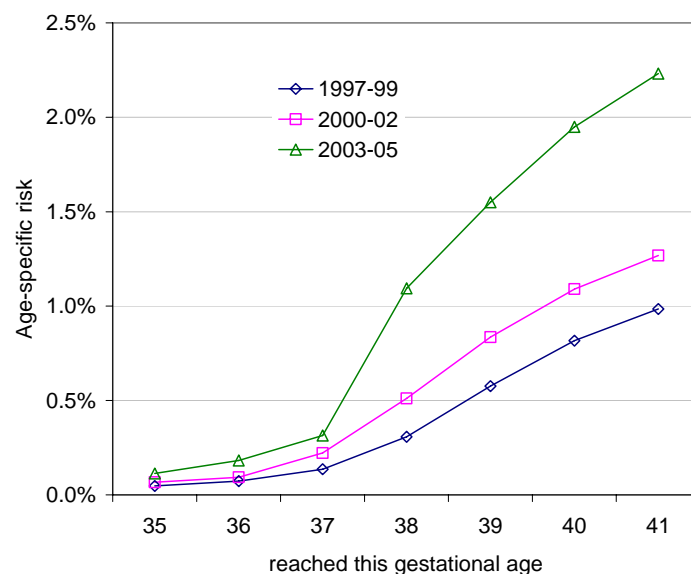Figure 3. Cesarean Without Trial of Labor Low-Risk Nulliparas

	37 weeks	38 weeks	39 weeks
1997-99	0.1%	0.3%	0.6%
2003-05	0.3%	1.1%	1.6%

By the final period in the study, the 38-week rate of 1.1% was almost double the 39-week rate during the earliest period, 0.6%. This suggests a tendency to perform cesareans not only more frequently, but at least a week earlier in the pregnancy.

Multiparas (women with one or more previous live births) who have not had a previous cesarean are a subgroup that typically experience a much lower rate of cesarean delivery. Figure 4 indicates,

Figure 4. Cesarean Without Trial of Labor Low-Risk Multiparas

however, that through 39 weeks about the same rates pertain to low-risk multiparas, with a similar shift over the study period. For example, cesarean rates among this population of women were:
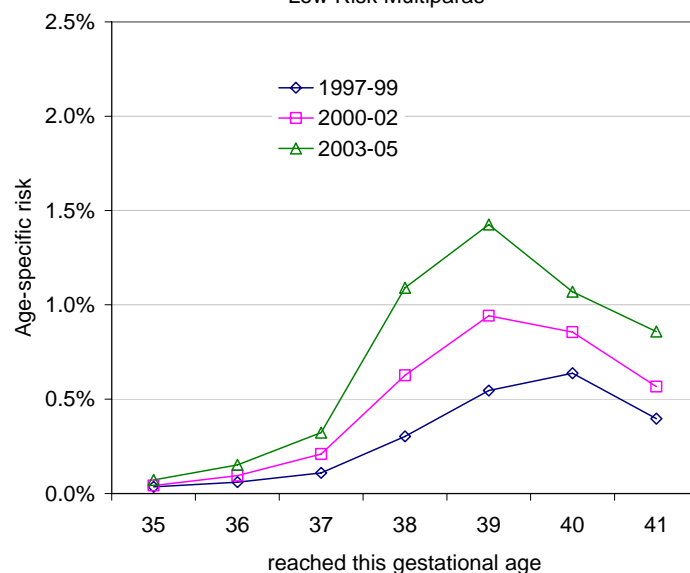
	37 weeks	38 weeks	39 weeks
1997-99	0.1%	0.3%	0.6%
2003-05	0.3%	1.1%	1.4%

The major difference from nulliparas is that cesarean rates among these multiparas decline in later weeks.

Multiparas who have had a previous cesarean delivery are at much higher risk for *repeat* cesarean. Figure 5 demonstrates this, and also shows a shift over time very comparable to other groups. For example, cesarean rates among this population of women were:

	37 weeks	38 weeks	39 weeks
1997-99	3.6%	14%	27%
2003-05	7.5%	31%	58%

Rates decline at later gestational ages, suggesting an increasing proportion of women who opt for VBAC.

The rates at 37 and 38 weeks are particularly worthy of note considering ACOG guidelines. In the 1997-99 period, the chance that a repeat cesarean would be performed at 37 weeks to a woman who had not delivered already was 3.6%, and 14% at 38 weeks. By the latter 2003-05 period, 7.5% of women in this category underwent cesareans after reaching 37 weeks, and 31% after reaching 38 weeks. These

Figure 5. Repeat Cesarean Without Trial of Labor
Low-Risk Multiparas with Prior Cesarean

rates are at least 20 times higher than for comparable women without a prior cesarean, suggesting that they include a large proportion of elective procedures. The cumulative effect of this tendency toward early delivery is quite substantial. In the 1997-99 period about 40% of all repeat cesareans were performed before 39 weeks, and by the 2003-05 period that share had increased to 50%.
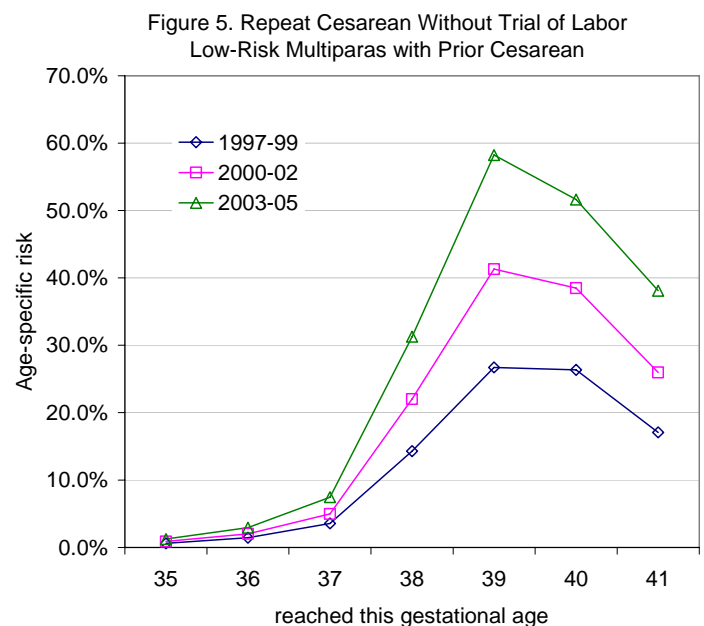
Artificial Induction of Labor to Low Risk Mothers

Induction of labor, with the intention of a vaginal delivery, is a much more frequent obstetric intervention than no-trial cesarean. As shown in Figure 6, the risk of induction for low-risk nulliparas increases steadily with duration of gestation. The risk-by-age curves for each time period begin to diverge at 37 weeks. For example, induction rates among this population of women were:

Figure 6. Induction of Labor
Low-risk Nulliparas

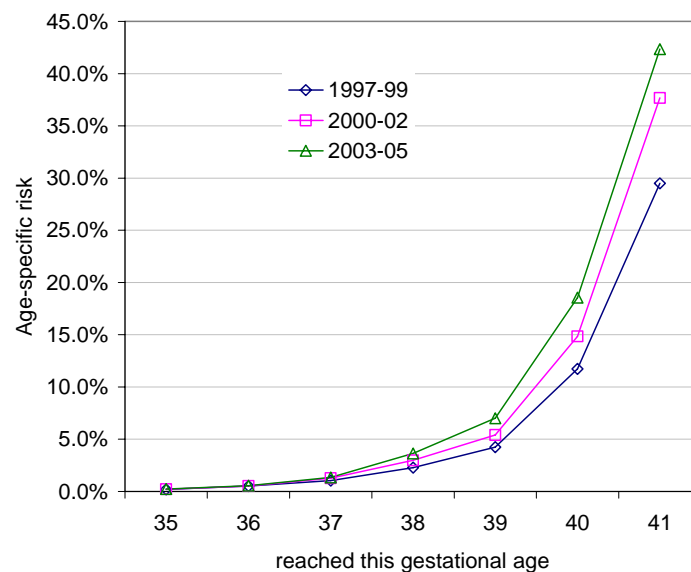|	38 weeks	39 weeks	40 weeks
1997-99	2.3%	4.2%	11.7%
2003-05	3.6%	7.0%	18.6%

Figure 6 clearly has implications for the ACOG target of 39 weeks gestation. The incidence of induction at 38 weeks in the 2003-05 period, 3.6%, was very nearly as high as it was at 39 weeks six years earlier. But the risk-by-age curve can be thought of as having generally shifted to the left, by approximately one half week.

Induction of labor at any gestational age is associated with higher risk of cesarean delivery. As Figure 7 shows, until 39 weeks of gestation, cesarean rates are at least double that for deliveries beginning with spontaneous labor. For example, cesarean rates at 39 weeks among this population of women were:

Figure 7. Cesarean Delivery After Induction of Labor
Low risk Nulliparas

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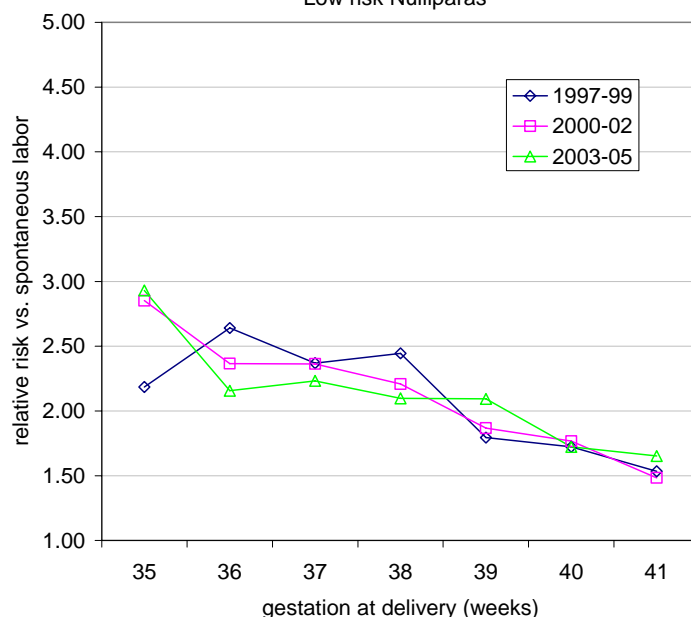
	Spontaneous labor	Induced labor
1997-99	13.6%	24.4%
2003-05	17.1%	35.8%

There is no consistent pattern of change in this relative risk within the study period.

Figure 8 repeats the analysis of labor induction for low-risk multiparas. Again, the period-specific curves begin to diverge at 37 weeks of gestation. For example, induction rates among this population of women were:

	38 weeks	39 weeks	40 weeks
1997-99	2.8%	5.1%	11.1%
2003-05	4.8%	9.0%	16.7%

Similar to low-risk nulliparas, during the nine-year study period, the 38-week rate increased to 4.8%, nearly the earlier rate at 39 weeks, and the 39-week rate of 9.0% nearly matched the earlier 40-week rate.

Figure 9 shows the relationship between gestational age at induction and cesarean risk, generally similar to that for nulliparas. The risk generally decreases as gestational age increases, but never falls below 1.5 times the rate for spontaneous

Figure 8. Artificial Induction of Labor
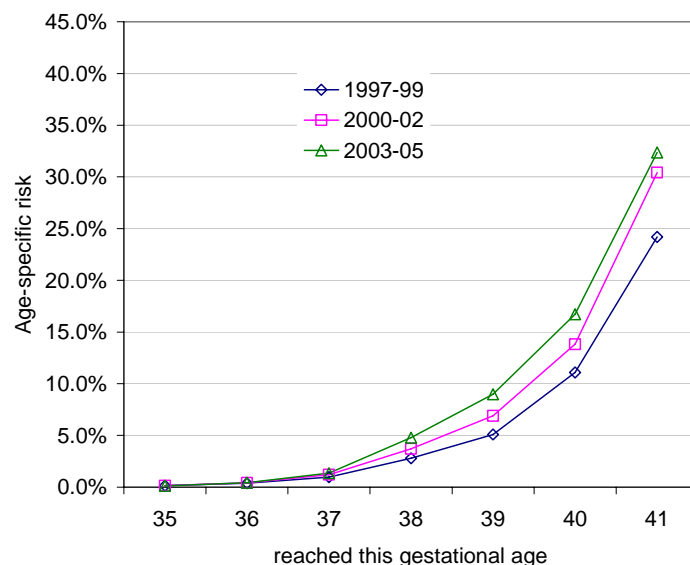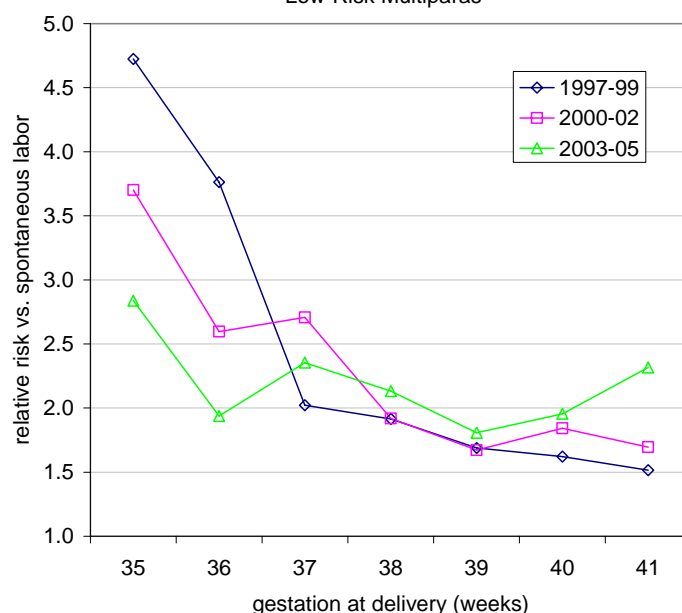Low-Risk Multiparas

Figure 9. Cesarean Delivery After Induction of Labor
Low-Risk Multiparas

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labors. For example, cesarean rates at 39 weeks among this population of women were:

	Spontaneous labor	Induced labor
1997-99	2.3%	4.0%
2003-05	3.3%	6.0%

The apparent divergences at 40-41 weeks in Figure 9 are likely random noise, given the low rates.

The Overall Rise in Prematurity

The cumulative effect of rising rates of labor induction and cesarean delivery at earlier gestational ages is an absolute increase in the proportion of all deliveries prior to 39 completed weeks of gestation. Over the study period the proportion of deliveries to low-risk nulliparas increased from 25% to 29%, and deliveries to multiparas (without prior cesarean) increased from 28% to 33%. As shown in Figure 10, the majority of deliveries between 35 and 38 weeks are the result of spontaneous labor, and the number of them has remained virtually unchanged over the study period. The number and relative contribution of inductions and cesareans has made virtually all the difference for these women.

In Figure 11, we see a very similar pattern for low-risk multiparas (without previous cesarean), with slightly larger rates of increase for each category of delivery. In both groups, the number of these "near term" deliveries[1] associated with induction increased by about half over the study period, and the number that were no-trial cesareans tripled.

Figure 10. Live Births at 35-38 Weeks Gestation Low-risk Nulliparas
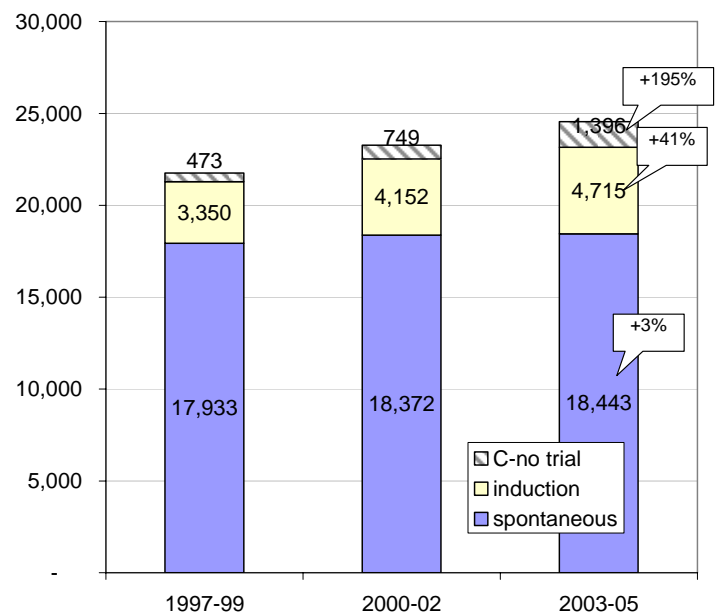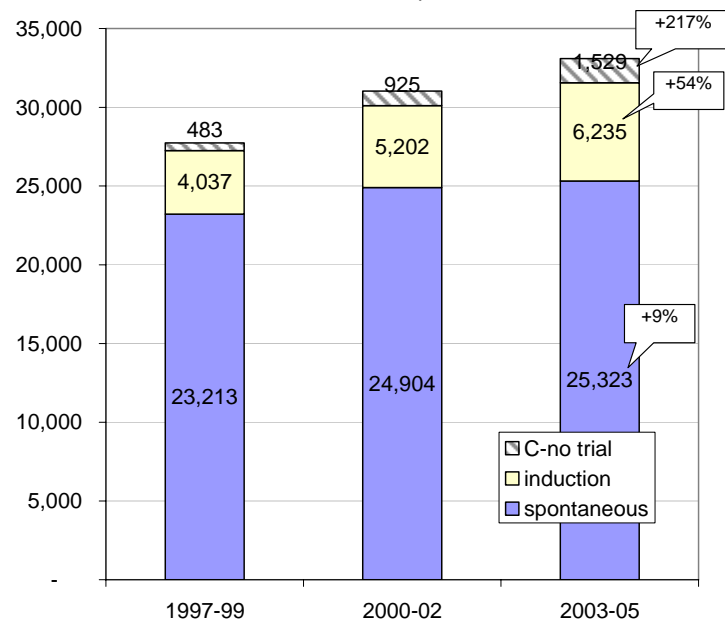
Figure 11. Live Births at 35-38 Weeks Gestation Low-risk Multiparas

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[1] "Near term" is intended to include "late preterm" (35-36 weeks) plus 37-38 week infants. The latter are usually considered "term" in epidemiological studies but fall short of the 39 weeks posited as fully mature by ACOG.

Neonatal Morbidity Related to Prematurity and Method of Delivery

In this section we consider the relationship between gestational age at delivery and indicators of neonatal morbidity available at hospital discharge. This relationship is further stratified by the circumstances of labor: cesarean delivery without a trial of labor, induction or spontaneous labor. While the risk of morbidity is related to the ultimate route of delivery, e.g., cesarean versus vaginal delivery after either spontaneous or induced labor, we focus on how labor was initiated in order to examine the consequences of that choice. We discovered no differences in this analysis of morbidity between nulliparas and multiparas, so the data were combined. Data on neonatal morbidity are presented only for the 2003-05 period, to most accurately depict the consequences of current utilization and scheduling of labor induction and cesarean delivery.

Figure 12 presents this analysis for two diagnoses of respiratory difficulty in the newborn, respiratory distress syndrome and/or transient tachypnea, when accompanied by mechanical ventilation or CPAP. Incidence of this condition is higher at every gestational age following no-trial cesarean delivery, and for every circumstance of labor declines steadily as gestational age advances.

For example, the incidence of respiratory difficulty for an infant induced at 38 weeks is 0.54%, compared to 0.39% at 39 weeks. This is a difference of 1.5 infants per 1,000 deliveries. Spontaneous labor at 39 weeks is associated with an even lower incidence of 0.30%. Direct comparison between spontaneous labor and other circumstances is complicated by not being able to control when spontaneous labor will occur. Therefore it might be

Figure 12. Respiratory Condition Requiring CPAP or Ventilation
Low-risk deliveries 2003-05
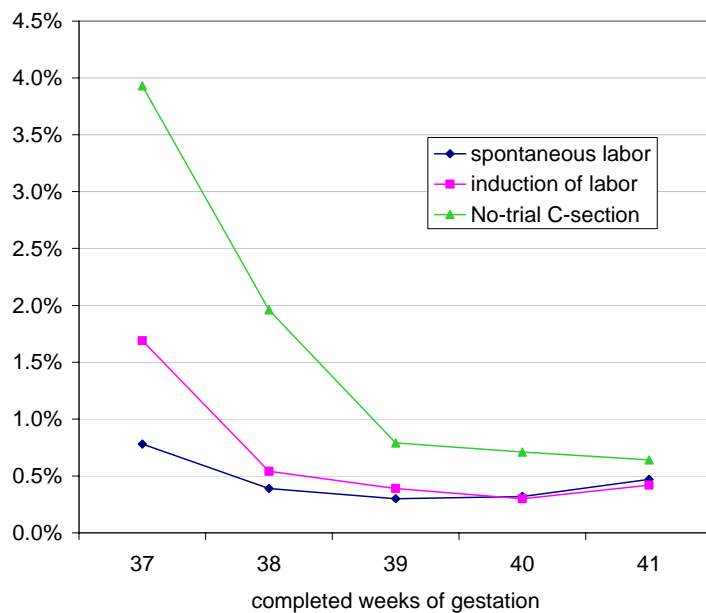
more appropriate to compare an induced labor at 38 or 39 weeks to spontaneous labor at 40 weeks, which would suggest a larger differential in risk than comparing the two circumstances at the same gestational age.

Figure 13 presents the age-specific incidence of diagnosis of hyperbilirubinemia serious enough to require phototherapy. As in the previous figure, rates decline consistently with gestational age. There is more separation here between spontaneous and induced labor, and less for no-trial cesarean. For example, delivery at 38 weeks carries a risk of 3.9% for no-trial cesareans, 2.8% for induced labor, and 2.2% for spontaneous labor. All can be compared to the 1.5% for spontaneous labors delivered at 40 weeks.
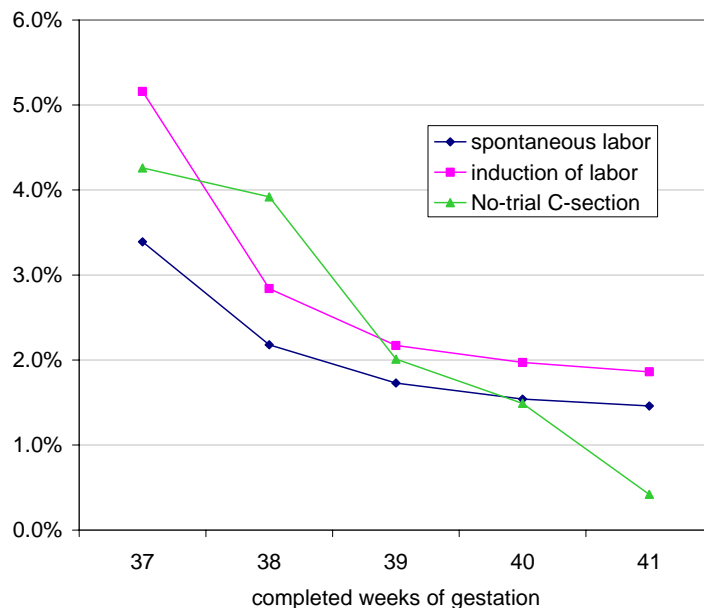
Figure 14 presents risk-by-age curves for admission to the ICU for two or more days (overnights), a generic measure of moderate to severe morbidity. Although the incidence is higher, the pattern is similar to that for respiratory difficulties. There was a large difference between no-trial cesareans and other deliveries and a strong decline through 39 weeks, to about 2% for all deliveries with a trial of labor. There is an increase in incidence at 41 weeks for deliveries involving either intervention.

Figure 13. Hyperbilirubenemia Requiring Phototherapy
Low-risk deliveries 2003-05

Figure 14. Neonatal ICU Admission 2+ Days
Low-risk deliveries 2003-05
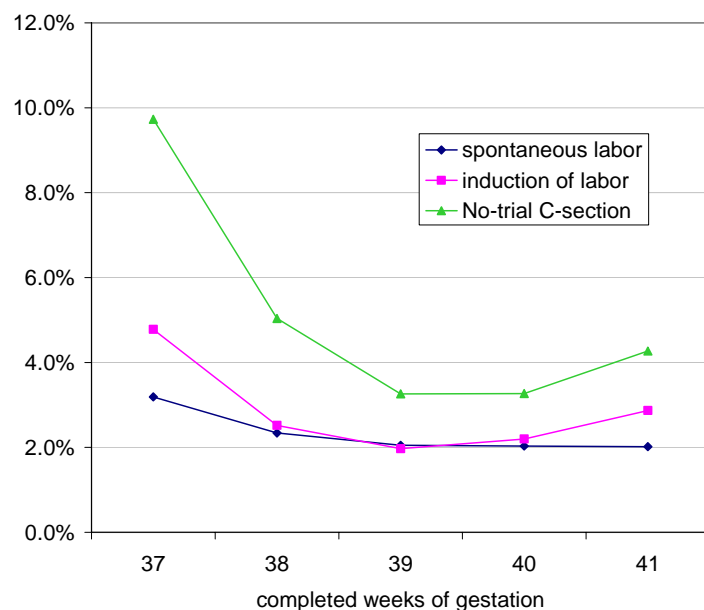
Summary and Discussion

The practice of obstetrics is complex and evolving. It is not feasible to delineate and monitor global "standard practice" for every eventuality. It is possible, however, to identify a population of births for which spontaneous labor and vaginal delivery would be the normal standard of care, and to assess trends in the care actually received by this population. The excluded group includes multiple gestations, breech presentations, prior cesareans, maternal hypertension and other indications; these are all subjects of ongoing deliberation about clinical risks and benefits that is beyond the investigative scope of this kind of epidemiological analysis.

The analysis in this study focused on standard presentations—singleton and head-down—and included nulliparas and multiparas with all previous vaginal deliveries. These criteria account for 80% of all births, and 48% of all cesarean deliveries. We also excluded about 25% of deliveries within this group that exhibited relatively common medical indications that typically warrant a delivery by medical intervention. The remainder is a carefully filtered population of relatively low-risk obstetric cases that should generally receive standard obstetric care according to well-established guidelines. From 1997 to 2005, this population comprised 60% of all births, 28% of all no-trial cesareans, 60% of all primary cesareans after a trial of labor, and 67% of all inductions.

Within this filtered population of births, this study has documented a substantial increase from 1997 to 2005 in the utilization of artificial labor induction and cesarean delivery at gestational ages that put newborns at risk for serious complications of prematurity. Some of the increase in these early deliveries may be justified by medical circumstances. But the fact that the rate of increase is so substantial, and occurs against a background of so little change in the incidence of prematurity involving spontaneous labor, must give us pause.

Two concerns are immediately suggested. One is that the general tolerance, even preference, for obstetric intervention has become too generous. In this low-risk population, we would argue that the preponderance of delivery interventions would be either purely elective or the preemptive management of

risk factors that have not manifest as complications. Numerous studies in New Jersey and elsewhere have concluded that increases in cesarean rates have far outstripped any population changes in medical risk. Therefore it is likely that, over a relatively short period of time, the same level of risk has come to be managed more aggressively. This study reinforces that conclusion, and adds evidence of the same sort for labor induction.

A second, related concern is that the definition of an optimally safe delivery date has been slowly creeping downward. Is 38 weeks "the new 39"? The pressures underlying this trend may come from many directions: mothers eager to finish being pregnant, physicians anxious to schedule their deliveries efficiently, hospitals rationalizing the availability of facilities and staff, etc. The pressures might reinforce, in spite of explicit ACOG guidelines, the individual perception that the compromises involved are inconsequential. Yet the evidence shows that this shift does adversely affect safety in the aggregate.

We noted that for both first-time mothers and multiparas, artificial induction of labor is associated with higher rates of emergency cesarean. This is true at all gestational ages, but the differential is larger the earlier induction occurs. A surprisingly large proportion of inductions "fail" in this sense (in 2008, over 40% for all standard-presentation nulliparas). This exposes both mother and infant to potentially severe complications which mothers may not completely understand when they consent to induction. It is important that gestational age *not* be the only criterion for assessing appropriate timing of induction. The condition of the cervix is extremely important and should be assessed at the proposed time of induction, and reassessed in the event that delivery is delayed (often ripening agents are employed). The trend toward earlier inductions is fighting both nature—ignoring the biological cue represented by the spontaneous onset of labor—and the statistics—risking a high failure rate when ignoring that timing cue.

This study also documents a clear difference in risk of various neonatal morbidities for infants across the very last weeks of full term pregnancy. The association of respiratory difficulties, subnormal liver function and NICU admission with delivery before 37 weeks is well established. Our analysis shows that risk of those complications of prematurity continue to recede with the completion of the 38th, 39th and

even the 40th week. For respiratory difficulties and NICU admission, we also see a heightened risk associated with no-trial cesarean that is independent of gestational age. The risk-by-age curves for induction and spontaneous labor essentially overlap, but this is misleading. The infant born after induction at 38 weeks should not necessarily be compared with a spontaneous labor at the same gestational age, but also with one spontaneously delivered at 39 or 40 weeks. Again, we think that spontaneous labor is a stronger timing cue than strict adherence to the calendar.

Premature birth is a leading contributor to neonatal morbidity and mortality. This study has focused on what we consider a best approximation of preventable prematurity that is caused by elective or discretionary utilization of labor induction and cesarean delivery at inappropriate gestational age. It is worth acknowledging the limits of that approximation strategy. In spite of our efforts to eliminate the most common and definitive indications for early delivery, it might still be true that other strong medical justifications exist for a large proportion of the residual interventions we are labeling as elective/preventable. To account for the upward trends we observe, such unmeasured causes would have to be increasing substantially in the *filtered* population we have identified. Large, autonomous increases in complications ranging from hypertensive disorders to placental anomalies have not been observed in the literature so far.

One very dramatic change in the population health of childbearing women is the obesity epidemic. Maternal obesity has been implicated in increasing incidence of hypertension, diabetes and fetal growth restriction *and* macrosomia. Of these, we have accounted for all but diabetes, a choice we made because *well-managed* diabetes should not complicate pregnancy or delivery. There is a plausible connection between extreme obesity and anatomically-based dystocia, but again this has not been documented in the magnitudes that would be necessary to account for the trends we observe here. Continuing research will no doubt lead to clearer conclusions, but we expect our basic conclusion to hold up—that elective and discretionary decisions in evolving "standard" practice are important contributors to current rates of early term delivery.

The Department of Health and Senior Services will continue to monitor this important element of safety in maternity care. This report, and others like it, represent an important bridge between State government's responsibility for epidemiological surveillance and the maintenance of effective medical care in New Jersey's highly professional but decentralized clinical settings. The Department will also continue to collaborate with hospitals, maternity care providers and other professional and health advocacy groups to promote the safest and highest quality prenatal and maternity care.

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