OBSTETRICS

Contemporary cesarean delivery practice in the United States

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OBJECTIVE: To describe contemporary cesarean delivery practice in the United States.

STUDY DESIGN: Consortium on Safe Labor collected detailed labor and delivery information from 228,668 electronic medical records from 19 hospitals across the United States, 2002-2008.

RESULTS: The overall cesarean delivery rate was 30.5%. The 31.2% of nulliparous women were delivered by cesarean section. Prelabor repeat cesarean delivery due to a previous uterine scar contributed 30.9% of all cesarean sections. The 28.8% of women with a uterine scar had a trial of labor and the success rate was 57.1%. The 43.8% women attempting vaginal delivery had induction. Half of cesarean for dystocia in induced labor were performed before 6 cm of cervical dilation.

CONCLUSION: To decrease cesarean delivery rate in the United States, reducing primary cesarean delivery is the key. Increasing vaginal birth after previous cesarean rate is urgently needed. Cesarean section for dystocia should be avoided before the active phase is established, particularly in nulliparous women and in induced labor.

Key words: cesarean delivery, induction, labor, vaginal birth after previous cesarean

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Cesarean delivery has become the most common major surgical procedure in many parts of the world.[1,2] The national rate of cesarean delivery in the United States has increased more than 50% since 1996 to 31.8% in 2007.[3] This upward trajectory appears likely to continue in the near future.

★ EDITORS' CHOICE ★

Reasons for the increase are multifaceted. Delayed childbearing, increasing maternal body mass, more multifetal gestations, and low use of vaginal birth after previous cesarean (VBAC) are commonly cited causes.[4,5] Cesarean delivery on maternal request[6] and physicians' fear of litigation due to a poor obstetric outcome[7] may also be contributing to the escalating rate of cesarean delivery. Despite anecdotal evidence and the common belief that certain cesarean deliveries may be unnecessary, the magnitude of unnecessary cesarean section at the national level is unknown. Reliable, detailed information on labor and delivery is often unavailable in a large population. Consequently, our understanding of the underlying causes of high cesarean rate is incomplete.

To meet this challenge, the *Eunice Shriver Kennedy* National Institute of Child Health and Human Development, National Institutes of Health, in collaboration with 12 institutions across the country, conducted a retrospective observational study entitled "the Consortium on Safe Labor." The goal of the study was to collect comprehensive information on contemporary labor and delivery practice in multiple institutions. This paper describes the contemporary cesarean delivery practice in the US population.

Materials and Methods

The Consortium on Safe Labor included 12 clinical centers (with 19 hos-

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For Editors' Commentary, see Table of Contents

pitals) across 9 American College of Obstetricians and Gynecologists (ACOG) US districts. There were 8 university affiliated teaching hospitals, 9 teaching community hospitals, and 2 nonteaching community hospitals. They were chosen because of the availability of electronic medical records at each institution and because their geographic distribution covers all ACOG US districts. A total of 228,668 deliveries with 233,844 newborns between 2002 and 2008 were included in the study. Between 2005 and 2007, 87% births occurred. All births at 23 weeks or later in these institutions were included. A total of 9.5% of women contributed more than 1 delivery to the database. To avoid intraperson correlation, we selected the first delivery from each subject in the study, leaving 206,969 deliveries for analysis. Participating institutions extracted detailed information from their electronic medical records on maternal demographic characteristics, medical history, reproductive, and prenatal history, labor, and delivery summary, postpartum and newborn information. Information from the neonatal intensive care unit (NICU) was linked to the newborn records. Data on labor progression were extracted from the electronic labor database. Information on hospital and physician characteristics was collected from surveys of the local investigators, and maternal and newborn discharge summaries (in International Classification of Diseases-9 codes) were linked to each delivery. This project was approved by the institutional review boards of all participating institutions.

Data transferred from the clinical centers were mapped to predefined common codes for each variable at the data coordinating center. Data inquiries, cleaning, recoding, and logic checking were performed. We also conducted validation studies for 4 key outcome diagnoses, including cesarean for nonreassuring fetal heart rate tracing, asphyxia, NICU admission for respiratory conditions, and shoulder dystocia. To validate data, eligible charts were selected, and investigators were asked to recollect data with chart abstraction done by hand. We compared the information hand collected from the medical charts with that downloaded from the electronic medical records. Appendix Table 1 indicates that most variables that were reviewed in this study are highly accurate. Although our records were not sampled randomly, the consistency among different records on the same variable (eg, singleton, gestational age, attempting vaginal birth, live birth, vertex presentation) indicates that the information provided in the validation studies is reliable and likely to be generalizable to the entire database. Thus, the electronic medical records are a reasonably accurate representation of the medical charts.

Approximately 5.9% of women in our study had missing information on fetal presentation. Given the importance of fetal presentation in our analysis, we performed multiple imputation.[8] A logistic regression model imputed the likelihood of vertex/nonvertex presentation in a particular subject multiple times based on other obstetric characteristics, including maternal race, parity, previous uterine scar, number of fetus, external cephalic version, smoking, placenta previa, cephalopelvic disproportion, gestational age, reason for admission to labor/delivery, trial of labor, induction, fetal scalp electrode, operative vaginal delivery, and mode of delivery. When the imputed data were analyzed, the uncertainty that was related to imputation was taken into account.

To make our study population reflect the overall US obstetric population and to minimize the impact of the various number of births from different institutions, we assigned a weight to each subject based on ACOG district, maternal race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and others), parity (nulliparous vs multiparous), and plurality (singleton vs multiple gestation). We first calculated the probability of each delivery with these 4 factors according to the 2004 National Natality data[9]; publicly available National Natality data can no longer be separated by state after 2004. Then, based on the number of subjects each hospital contributed to the database, we assigned a weight to each subject. Appendix Table 2 indicates that the weighted study population is close to the entire US obstetric population. Therefore, we used the weighted sample throughout our analyses.

We defined "attempting vaginal delivery or a trial of labor" as all vaginal deliveries plus cesarean deliveries with at least 2 vaginal examination data in the labor progression (or labor curve) database. For indications for cesarean delivery, we first listed all major indications and the percent of cesarean deliveries with a specific indication (1 woman may have more than 1 indication). "Elective cesarean delivery" was defined as cesarean for clinical indications of: (1) elective as denoted in the electronic medical record, (2) declining a trial of labor, and (3) a variety of factors that are not considered accepted indications for cesarean delivery such as elderly gravida, multiparity, remote from term, postterm/postdates, diabetes, chorioamnionitis, chronic or gestational hypertension without preeclampsia/eclampsia, premature rupture of the membranes, human papillomavirus infection, Group B streptococcus positive, polyhydramnios, fetal demise, tubal ligation, and social/religion concerns. We then grouped all indications into 3 hierarchical, mutually exclusive categories: "clinically indicated," "mixed," and "truly elective." The "mixed" group included cesarean deliveries where not enough detailed information (eg, human immunodeficiency virus with an unknown viral load or unknown presentation of twins) was available to judge the necessity or where the clinical indications were not that strong (eg, preeclampsia).

Duration of labor arrest was calculated as the duration of no appreciable change of cervical dilation in the first stage and the time interval between the first 10 cm and delivery in the second stage. "No appreciable change in cervical dilation" was defined as within 1 cm of change in dilation before delivery. All statistical analyses were performed using SAS version 9.1 (SAS Institute, Inc, Cary, NC). Given that this is a descriptive analysis with a very large sample size, no statistical testing was performed; nor were confidence intervals provided.

TABLE 1
Cesarean rate by maternal characteristics and type of cesarean delivery

Variable	Proportion of the population, %	Overall cesarean rate,[a] %	Primary cesarean delivery,[a] %	Repeat cesarean delivery,[a] %	Prelabor cesarean delivery,[a] %	Intrapartum cesarean delivery,[a] %
n (unweighted)	206,969	60,866	38,336	22,530	32,380	28,486
n (weighted)	3,997,436	1,220,877	727,941	492,935	696,583	524,294
Maternal age, y						
<20	8.6	21.0	18.8	2.2	6.6	14.5
20-24	22.6	24.6	16.5	8.1	11.7	12.9
25-29	27.0	28.1	16.6	11.5	15.9	12.3
30-34	24.7	33.6	18.9	14.9	20.6	13.2
35+	17.2	42.2	21.7	20.5	28.3	14.0
Race/ethnicity						
Non-Hispanic white	56.6	29.9	18.3	11.6	17.8	12.1
Non-Hispanic black	14.2	33.4	20.5	13.2	17.4	16.3
Hispanic	22.9	30.3	16.5	13.8	16.9	13.4
Asian/Pacific Islanders	3.2	30.6	19.6	11.1	15.5	15.2
Other	3.1	29.3	17.4	11.8	17.2	12.1
Health insurance						
Private	53.5	31.3	19.3	12.0	17.9	13.4
Public	33.3	31.6	18.1	13.6	17.9	13.8
Other/unknown	13.2	24.6	14.0	10.6	14.2	10.3
Body mass index at delivery, kg/m^2						
<25	13.5	22.3	14.0	8.4	13.8	8.6
25.0-29.9	37.7	25.6	15.8	9.8	14.5	11.1
30.0-34.9	27.6	32.6	19.3	13.3	18.4	14.3
35.0+	21.2	43.7	24.6	19.2	25.0	18.8
Parity						
Nulliparous	40.4	31.2	31.2	0.1	9.7	21.5
Multiparous	59.6	30.0	9.4	20.6	22.7	7.4
Number of fetuses						
Singleton	98.3	29.9	17.7	12.2	16.9	13.1
Multiple	1.7	65.9	47.0	18.9	50.6	15.3
Labor induction in women attempting vaginal delivery						
No	56.2	11.8	9.1	2.7	0	11.8
Yes	43.8	21.1	19.5	1.6	0	21.1
Previous uterine scar						
No	84.9	21.1	21.1	0	7.8	13.2
Yes	15.1	83.6	2.2	81.4	71.3	12.3
Vertex presentation (singleton only)						
No	5.1	92.8	71.1	21.6	73.8	19.0
Yes	94.9	26.6	14.9	11.7	13.8	12.8

Zhang. Contemporary cesarean delivery practice in the US. Am J Obstet Gynecol 2010.

(continued)

TABLE 1
Cesarean rate by maternal characteristics and type of cesarean delivery *(continued)*

Variable	Proportion of the population, %	Overall cesarean rate,[a] %	Primary cesarean delivery,[a] %	Repeat cesarean delivery,[a] %	Prelabor cesarean delivery,[a] %	Intrapartum cesarean delivery,[a] %
Hospital type						
University affiliated teaching hospital	60.7	32.9	19.4	13.5	19.5	13.5
Teaching community Hospital	35.9	27.2	16.7	10.5	14.5	12.8
Nonteaching community hospital	3.4	23.1	12.8	10.4	12.6	10.5

[a] Overall cesarean rate = primary + repeat cesarean rates = prelabor + intrapartum cesarean rates. Repeat cesarean section includes cesarean section after previous myomectomy in nulliparous women (0.1%).

Zhang. Contemporary cesarean delivery practice in the US. Am J Obstet Gynecol 2010.

RESULTS

The overall rate of cesarean delivery in our cohort was 30.5%, varying from 20% to 44% among the participating hospitals. Table 1 presents the overall and specific categories of cesarean delivery (primary vs repeat, and prelabor vs intrapartum) by maternal characteristics. With advancing maternal age, the overall cesarean rate doubled from 21.0% at age <20 years to 42% in women 35 years or older, mainly due to repeat, prelabor cesarean deliveries. Obesity was associated with substantially higher cesarean rates in all categories. One in 3 nulliparous women was delivered by cesarean section (31.2%). Multiparous women had an overall cesarean rate similar to that of nulliparous women (30.0%), primarily due to prelabor, repeat cesarean delivery.

A total of 65.9% multifetal gestations were delivered by cesarean section (in comparison to 29.9% in singleton pregnancies), and a majority of multifetal gestations did not attempt vaginal delivery. The induction rate was 36.2%, using all deliveries as the denominator, or 43.8% among women attempting vaginal delivery. The cesarean rate was twice as high in induced labor than in spontaneous labor in all pregnancies (21.1% vs 11.8%) and in singleton nulliparous women with vertex presentation (31.4% vs 14.2%). In women with a previous uterine scar, 28.8% had a trial of labor. Among them, the rate of successful VBAC was 57.1%. Overall, 83.6% of women with a uterine scar were delivered by cesarean section. A total of 92.8% fetuses with nonvertex presentation were delivered by cesarean section.

TABLE 2
Relative contribution of obstetric factors

Robson classification[a]	Obstetric characteristics	Proportion of all deliveries, %	Rate of prelabor cesarean delivery, %	Rate of intrapartum cesarean delivery, %	Proportion of all cesarean deliveries, %
1	Nulliparous, singleton, vertex, ≥37 wk, spontaneous labor	16.5	—	14.8	8.0
3	Multiparous, singleton, vertex, ≥37 wk, no uterine scar, spontaneous labor	20.9	—	3.1	2.1
2a + 4a	All women, singleton, vertex, ≥37 wk, no uterine scar, induced labor	30.9	—	19.0	19.2
2b + 4b	All women, singleton, vertex, ≥37 wk, no uterine scar, prelabor cesarean delivery	2.4	100	—	7.9
5	All women, singleton, vertex, ≥37 wk, uterine scar	11.5	70.2	11.8	30.9
10	All women, singleton, vertex, <37 wk, regardless uterine scar	11.1	21.5	14.2	13.0
6 + 7 + 8 + 9	All women, multiple gestation or nonvertex presentation, regardless uterine scar	6.7	67.7	17.9	18.8
	Overall	100%			100%

[a] Based on classification scheme proposed by Robson.[10]

Zhang J. Contemporary cesarean delivery practice in the US. Am J Obstet Gynecol 2010.

TABLE 3
Main recorded indications for cesarean delivery

Indication	Prelabor cesarean delivery, %	Intrapartum cesarean delivery, %
Individual indications[a]		
Previous uterine scar	45.1	8.2
Failure to progress/cephalopelvic disproportion	2.0	47.1
Elective[b]	26.4	11.7
Nonreassuring fetal testing/fetal distress	6.5	27.3
Fetal malpresentation	17.1	7.5
Hypertensive disorders	3.1	1.6
Fetal macrosomia	3.3	1.2
Multiple gestation	2.8	0.8
Grouped indications (hierarchical, mutually exclusive)		
Clinically indicated[c]	9.7	74.9
Mixed[d]	80.7	23.0
Truly elective[e]	9.6	2.1
Total	100	100

[a] Women may have more than 1 indication. The total percentage may exceed 100%; [b] Indications for elective cesarean delivery include "elective", declining trial of labor, elder gravid, multiparity, remote from term, postterm/postdates, diabetes, chorioamnionitis, chronic or gestational hypertension without preeclampsia/eclampsia, premature rupture of the membranes, human papillomavirus infection, Group B streptococcus positive, polyhydramnios, fetal demise, tubal ligation, and social/religion concerns; [c] Clinically indicated includes emergency, non-reassuring fetal heart rate tracing/fetal distress, failure to progress, cephalopelvic disproportion, failed induction, failed forceps, failed vaginal birth after previous cesarean, placenta abruption, placenta previa, shoulder dystocia, and history of shoulder dystocia; [d] Mixed includes: previous uterine scar, breech/malpresentation, fetal anomalies, fetal macrosomia, human immunodeficiency virus infection, multiple gestation, preeclampsia/eclampsia, other; [e] Truly elective: without any indication in the "clinically indicated" or "mixed" categories.

Zhang. Contemporary cesarean delivery practice in the US. Am J Obstet Gynecol 2010.

To further examine the relative contribution of obstetric factors to the cesarean rate, we grouped the women into 7 categories according to the classification scheme proposed by Robson.[10] Table 2 indicates that term pregnancies with a vertex, singleton fetus, and previous uterine scar contributed the most cesarean deliveries in the United States (30.9%), followed by term gestations with a singleton, vertex fetus whose labor was induced (19.2%). Multifetal gestations and pregnancies with nonvertex presentation accounted for only 6.7% of all births but contributed to one-fifth of all cesarean deliveries.

The main indication for prelabor cesarean delivery was previous uterine scar, followed by fetal malpresentation (Table 3). Among intrapartum cesarean deliveries, approximately half of them were performed for "failure to progress" or "cephalopelvic disproportion," and more than a quarter were performed for indications of nonreassuring fetal testing or fetal distress. "Truly elective" cesarean delivery accounted for 9.6% of prelabor and 2.1% of intrapartum cesarean deliveries As some prelabor cesarean deliveries in the "mixed" group were eligible for a trial of labor (eg, single previous low transverse cesarean section and vertex-vertex twin gestation), the "truly elective" cases may be an underestimate in the current study.

The cesarean rate was higher at the earlier gestational ages of delivery (Figure 1). For example, the cesarean delivery rate was over 60% at 28 weeks gestation and declined gradually with advancing gestation. In nulliparous women, intrapartum cesarean deliveries constituted the majority of cesarean sections at term (≥37 weeks). Among multiparous women, most cesarean deliveries occurred before the onset of labor across all gestational ages. Unlike in most women, the cesarean rate in women with a uterine scar did not decline with advancing gestation until 40 weeks.

We further examined the timing of cesarean delivery relative to cervical dilation among those women with vertex, singleton gestation attempting vaginal delivery (Figure 2). Induced labor was associated with twice as many cesarean deliveries as spontaneous labor in both nulliparous and multiparous women before and after 39 weeks, and the cesarean section was performed earlier in terms of cervical dilation in induced labor than in spontaneous labor. The cesarean rate was substantially higher in women with a uterine scar (47% and 33% before and after 39 weeks, respectively), and the cesarean section was performed at lower cervical dilation before 39 weeks than after 39 weeks.

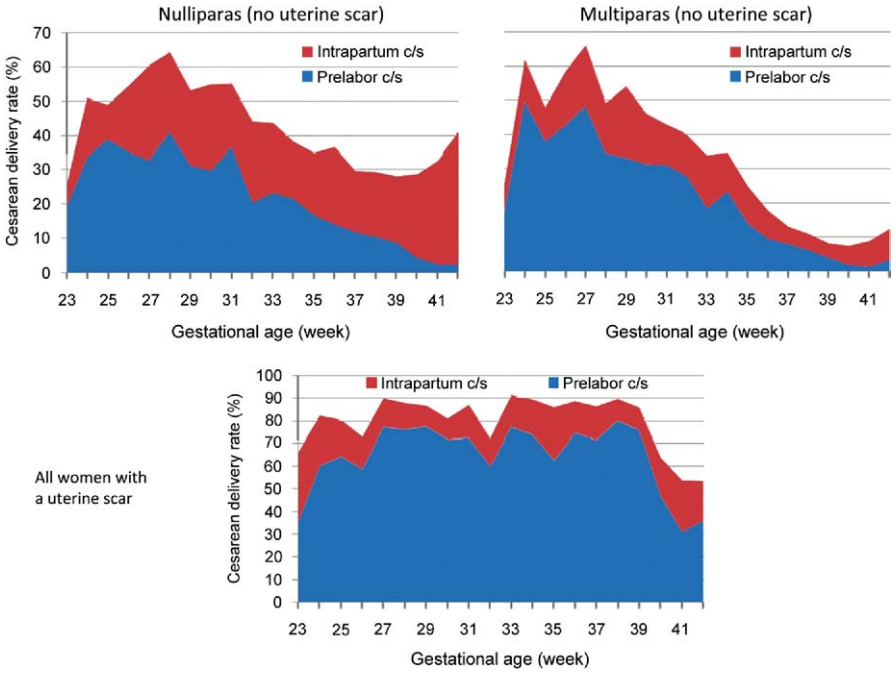
Table 4 presents total duration of labor arrest before intrapartum cesarean delivery for "failure to progress," "cephalopelvic disproportion," or "failed induction" among singleton, vertex presentation with, and without a uterine scar. The duration of labor arrest declined as labor advanced. At 4 cm of cervical dilation, for example, the median duration for nulliparous women was 4 hours and less than 3 hours at 6 cm. The duration was similar between spontaneous and induced labors. However, nearly half of cesarean sections were performed before 6 cm in induced labor and in women with a previous uterine scar. One-third of cesarean deliveries at the second stage were performed at less than 3 hours in nulliparous women, whereas, a quarter were performed at less than 2 hours in multiparous women.

COMMENT

Our study is a large, contemporary assessment of cesarean delivery practice for the US obstetric population. We found that:

- One in 3 nulliparous women was delivered by cesarean section.
- Prelabor repeat cesarean delivery due to a previous uterine scar was the most common reason for cesarean section, contributing almost a third of all ce-

FIGURE 1
Cesarean delivery rate by gestational age



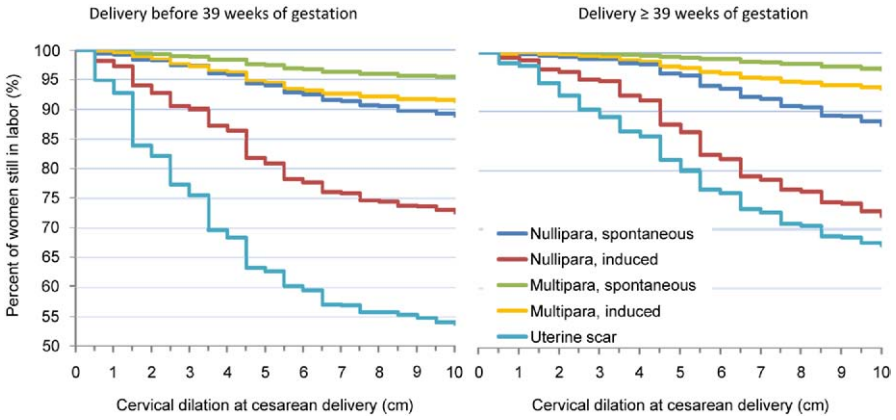
Cesarean delivery rate by type of cesarean (prelabor vs intrapartum), gestational age and parity (nulliparous women, multiparous women, and women with a uterine scar).

Zhang. Contemporary cesarean delivery practice in the US. Am J Obstet Gynecol 2010.

sarean deliveries. In contrast, the rate of trial of labor is disappointingly low, and the associated success rate for vaginal birth has declined.

- Approximately 44% of women attempting vaginal delivery had induced labor, and that within this group the cesarean rate was twice as high as in women with spontaneous labor.
- A high percentage of intrapartum cesarean deliveries were performed before 6 cm of cervical dilation, particularly in nulliparous women, induced labor, and women attempting VBAC.

FIGURE 2
Cervical dilation at cesarean delivery



Cervical dilation at intrapartum cesarean delivery among women attempting vaginal delivery by parity, onset of labor (induced vs spontaneous onset), previous uterine scar in singleton gestations.

Zhang. Contemporary cesarean delivery practice in the US. Am J Obstet Gynecol 2010.

VBAC

The VBAC rate experienced precipitous decline since 1996, which coincided with an over 50% increase in cesarean rate during the same period.[3] Our study indicates that prelabor repeat cesarean sections currently have a profound impact on the overall cesarean rate. Some experts estimate that two-thirds of women with a uterine scar are eligible for a trial of labor.[11] Yet, the rate of trial of labor is quite low in the United States. In 1999-2002, Landon et al[12] reported a rate of 38.9% in a NICHD Maternal-Fetal Medicine Unit Research Network study. The rate of trial of labor declined significantly from 48.3% in 1999 to 30.7% in 2002. This is consistent with our finding that the rate was 28.8% in 2005-2007, and ours may be an overestimate for the national level because academic institutions are overrepresented in our study. The low rate of trial of labor has been attributed in part to a slight increase in absolute risks of maternal and neonatal morbidity, professional liability concerns and physician and patient's attitude toward VBAC.[5] The recent change in ACOG recommendations also has reduced the availability of VBAC services in many hospitals.[13]

The success rate of attempted VBAC in our study was markedly lower (57.1%) than that in previous large studies. Lieberman et al[14] noted a VBAC success rate of 87% in 41 birth centers in 1990-2000. Macones et al[15] found a success rate of 75.5% in a regional study with 17 hospitals in 1996-2000, similar to that found by Landon et al[12] (73.4%). Gregory et al,[16] using 2002 California hospital discharge data, reported an overall success rate of 67%. One possible explanation of our finding is that the success rate of attempted VBAC is more recently influenced by other factors. Physicians and patients may be less committed even during a trial of labor.[17] For instance, half of the intrapartum cesarean sections for dystocia were performed before 6 cm of cervical dilation in our study. Many women may not be in active phase before that time.[18] The frequency of oxytocin

TABLE 4
Duration of labor arrest (in hours) prior to intrapartum cesarean for "failure to progress/cephalopelvic disproportion" or "failed induction"

	Nulliparous women		Multiparous women		
Cervical dilation at cesarean section, cm	Spontaneous labor, median (cumulative percentage)	Induced labor, median (cumulative percentage)	Spontaneous labor, median (cumulative percentage)	Induced labor, median (cumulative percentage)	Women with a previous uterine scar having a trial of labor, median (cumulative percentage)
0	13.8 (0.3)	14.5 (4)	— (0.1)	16.0 (2)	9.6 (2)
1	10.0 (2)	9.4 (10)	— (1)	11.7 (6)	6.3 (6)
2	6.8 (3)	5.6 (15)	— (3)	8.6 (9)	6.5 (16)
3	4.0 (7)	4.3 (23)	6.9 (6)	5.5 (16)	5.0 (21)
4	4.0 (17)	4.0 (40)	2.7 (14)	3.4 (29)	2.5 (36)
5	3.5 (28)	3.2 (53)	4.0 (19)	2.4 (44)	2.8 (49)
6	2.9 (38)	2.8 (63)	3.6 (31)	2.5 (54)	3.2 (62)
7	2.8 (46)	2.2 (69)	2.8 (39)	2.6 (63)	2.4 (69)
8	3.0 (56)	2.6 (75)	2.8 (53)	2.9 (71)	2.0 (75)
9	2.2 (65)	2.3 (81)	2.8 (69)	1.7 (83)	1.3 (84)
Second stage	3.8 (100)	3.5 (100)	2.9 (100)	2.8 (100)	2.3 (100)
Among the second stage cesarean deliveries (cumulative percentage)					
<2 h	12	14	24	27	39
2-3 h	33	35	55	63	56
3-4 h	55	63	74	81	76
≥4 h	100	100	100	100	100

—, the number of subjects is too small to have a meaningful value.

Zhang. Contemporary cesarean delivery practice in the US. Am J Obstet Gynecol 2010.

use for labor augmentation in the trial of labor was one-sixth of that in multiparous women without a uterine scar.

Another possible reason for the low success rate may be related to our definition of "a trial of labor." A woman with a uterine scar, minimal dilation, and 2 pelvic examinations recorded in the labor database would have been considered a trial of labor. Such cases may have increased the VBAC rate but reduced the success rate. However, findings of vaginal examinations that were entered in the labor progression (labor curve) computer system on the labor floor are often an indication for intended vaginal delivery. Thus, the above scenario may not have substantially affected our results.

Induction of labor

In parallel with the increasing cesarean rate, the rate of labor induction also has increased significantly in many developed countries, including a doubling of the US rate between 1990-2000 (from 9.5% in 1990 to 20.2% in 2000, and 22.6% in 2006).[19] In comparison, the overall induction rate was 35.2% in our study (around 2006); the induction rate in women attempting vaginal delivery was 43.8%. These findings suggest that the national figures based on birth certificates may have been an underestimate of the true national induction rate.[20]

For medically indicated induction of labor, the benefits for the mother and/or the fetus are indisputable. However, controversies arise when labor is induced for women with absent or marginal clinical indications.[21-23] Our data show that induced labor was twice as likely to result in cesarean delivery than spontaneous labor. Half of cesarean sections for dystocia in induced labor were performed before 6 cm of dilation, suggesting that clinical impatience may play a role in decision making. Some studies also suggest that induction of labor increases the risk of postpartum hemorrhage and blood transfusion.[22] Therefore, although more research is warranted, caution is needed to perform elective labor induction, as it may result in maternal morbidity and repeat cesarean deliveries in subsequent pregnancies.

Timing of intrapartum cesarean delivery

The high proportion of intrapartum cesarean deliveries performed before 6 cm of cervical dilation is concerning, particularly in nulliparous women and in induced labor. The active phase of labor is typically considered starting at 4 cm of dilation.[24,25] However, a recent study showed that multiparous women may not start the active phase until 6 cm, whereas, nulliparous women may not have a typical active phase of labor.[18] In contemporary nulliparous women who had vaginal delivery and normal perinatal outcome, labor may not progress for 6

hours at 4 cm or 3 hours at 5 cm of dilation (results not shown). In the current study, the median duration of labor arrest in nulliparous women, including periods before and after any intervention, was 4 hours at 4 cm. Thus, a cesarean section for dystocia before 6 cm in nulliparous women appears too soon in some cases.

We also found that one-third of cesarean deliveries at the seond stage were performed at less than 3 hours in nulliparous women, whereas, a quarter were performed at less than 2 hours in multiparous women. This is of concern because ACOG guidelines define arrest of descent as greater than 3 hours in nulliparous women with epidural analgesia and greater than 2 hours in multiparous women with epidural analgesia.[26] Given that 90% of the subjects used epidural analgesia and that the median duration in the second stage arrest included "decision-to-incision" time, the true waiting period in the second stage arrest appears shorter than ACOG recommendations in many cesarean cases.

It should be noted that even though we selected 12 institutions across 9 ACOG districts, our study subjects were not a random sample of all births in the United States. Academic institutions are overrepresented in our cohort. This may in part explain why our weighted preterm birth rate was higher (14.1%) than the national average (12.8% in 2006)[19] and why the induction rate in our study was higher than the published national average. Yet, our overall cesarean rate was slightly lower than the corresponding national average (30.5% vs 31.1% in 2006).[19] Nonetheless, for the first time we were able to separate cesarean delivery by prelabor and intrapartum in a large multicenter study. Our study provides detailed information on when cesarean section was performed, allowing us to identify potential areas for optimal management.

In summary, our study shows that 1 in 3 nulliparous women is delivered by cesarean section, which has a tremendous impact on subsequent prelabor repeat cesarean delivery. Prelabor repeat cesarean delivery now contributes almost a third of all cesarean deliveries. To make a significant impact on the high cesarean delivery rate in the United States, the focus should be preventing unnecessary primary cesarean deliveries from several aspects. First, we need to decrease the rate of cesarean delivery associated with a high rate of induction of labor. Cesarean section for dystocia should be avoided before active phase of labor is established particularly in nulliparous women, induced labor, and VBAC attempts. Second, there should be a clinically accepted indication for performing cesarean delivery. Finally, increasing access to and patient education on trial of labor in women with a previous uterine scar and improving the success rate are urgently needed. ■

REFERENCES

1. Villar J, Valladares E, Wojdyla D, et al. Caesarean delivery rates and pregnancy outcomes: the 2005 WHO global survey on maternal and perinatal health in Latin America. Lancet 2006; 367:1819-29.

2. Lumbiganon P, Laopaiboon M, Gülmezoglu AM, et al. Method of delivery and pregnancy outcomes in Asia: the WHO global survey on maternal and perinatal health 2007-08. Lancet 2010;375:490-9.

3. Hamilton BE, Martin JA, Ventura SJ. Births: preliminary data for 2007. National Vital Statistics Reports, Web release; vol. 57 no. 12. Hyattsville, MD: National Center for Health Statistics. Released March 18, 2009.

4. Joseph KS, Young DC, Dodds L, et al. Changes in maternal characteristics and obstetric practice and recent increases in primary cesarean delivery. Obstet Gynecol 2003;102: 791-800.

5. Macones GA. Clinical outcomes in VBAC attempts: what to say to patients? Am J Obstet Gynecol 2008;199:1-2.

6. Habiba M, Kaminski M, Da Fré M, et al. Cesarean section of request: a comparison of obstetricians' attitudes in eight European countries. BJOG 2006;113:647-56.

7. Murthy K, Grobman WA, Lee TA, Holl JL. Association between rising professional liability insurance premiums and primary cesarean delivery rates. Obstet Gynecol 2007;110:1264-9.

8. Rubin DB. Multiple imputation for nonresponse in surveys. New York: John Wiley; 1987.

9. Martin JA, Hamilton BE, Sutton PD, et al. Births: final data for 2004. National Vital Statistics Reports; vol. 55 no. 1. Hyattsville, MD: National Center for Health Statistics. 2006.

10. Robson SM. Can we reduce the cesarean section rate? Best Practice Res Clin Obstet Gynaecol 2001;15:179-94.

11. Landon MB. Vaginal birth after cesarean delivery. Clin Perinatol 2008;35:491-504.

12. Landon MB, Hauth JC, Leveno KJ, et al. Maternal and perinatal outcomes associated with a trial of labor after prior cesarean delivery. N Engl J Med 2004;351:2581-9.

13. Roberts RG. Deutchman M, King VJ, Fryer GE, Miyoshi TJ. Changing policies on vaginal birth after cesarean: impact on access. Birth 2007;34:316-22.

14. Lieberman E, Ernst EK, Rooks JP, Stapleton S, Flamm B. Results of the national study of vaginal birth after cesarean in birth centers. Obstet Gynecol 2008;111:285-91.

15. Macones GA, Peipert J, Nelson DB, et al. Maternal complications with vaginal birth after cesarean delivery: a multicenter study. Am J Obstet Gynecol 2005;193:1656-62.

16. Gregory KD, Korst LM, Fridman M, et al. Vaginal birth after cesarean: clinical risk factors associated with adverse outcome. Am J Obstet Gynecol 2008;198:452.e1-12.

17. Kalish RB, McCullough L, Gupta M, Thaler HT, Chervenak FA. Intrapartum elective cesarean delivery: a previously unrecognized clinical entity. Obstet Gynecol 2004;103:1137-41.

18. Zhang J, Troendle J, Mikolajczyk R, Sundaram R, Beaver J, Fraser W. The natural history of the normal first stage of labor. Obstet Gynecol 2010;115:705-10.

19. Martin JA, Hamilton BE, Sutton PD, et al. Births: final data for 2006. National Vital Statistics Reports; vol. 57 no. 7. Hyattsville, MD: National Center for Health Statistics; 2009.

20. Roberts CL, Bell JC, Ford JB, Morris JM. Monitoring the quality of maternity care: how well are labour and delivery events reported in population health data? Pediatr Perinatal Epidemiol 2009;23:144-52.

21. Vahratian A, Zhang J, Troendle JF, Sciscione AC, Hoffman MK. Labor progression and risk of cesarean delivery in electively induced nulliparas. Obstet Gynecol 2005;105: 698-704.

22. Grobman WA. Elective induction: when? Ever? Clin Obstet Gynecol 2007;50:537-46.

23. Nicholson JM, Parry S, Caughey AB, Rosen S, Keen A, Macones GA. The impact of the active management of risk in pregnancy at term on birth outcomes: a randomized clinical trial. Am J Obstet Gynecol 2008;198:511.e1-15.

24. Albers LL, Schiff M, Gorwoda JG. The length of active labor in normal pregnancies. Obstet Gynecol 1996;87:355-9.

25. Rouse DJ, Owen J, Hauth JC. Active-phase labor arrest: oxytocin augmentation for at least 4 hours. Obstet Gynecol 1999;93:323-8.

26. American College of Obstetricians and Gynecologists. Dystocia and augmentation of labor. ACOG practice bulletin no. 49. Obstet Gynecol 2003;102:1445-54.

APPENDIX

TABLE 1
Validity of data from electronic medical records comparing to medical charts in selected variables

Sample selection criteria	Information from the electronic medical records	Concordant with medical chart, %	Disagreed with medical chart, %	Not found in medical chart, %
Nulliparous, singleton, live, vertex fetus at admission, Attempting vaginal delivery and cesarean delivery due to non-reassuring fetal heart rate tracing (n = 5662)	Nulliparity	99.1	0.9	0.0
	Live fetus at admission	99.9	0.1	0.0
	Attempting vaginal delivery	96.2	3.6	0.2
	Singleton	98.5	0.1	1.4
	Vertex at admission	96.7	1.1	2.2
	Cesarean delivery	99.9	0.1	0.0
	Primary indication for cesarean delivery: nonreassuring fetal heart rate tracing/fetal distress	93.3	3.5	3.2
Singleton, gestational age ≥34 wk, attempting vaginal delivery, had an Apgar score at 5 min <4 or umbilical cord pH <7.0 or base deficit ≥12 mmol/L (n = 503)	Singleton	99.8	0	0.2
	Gestational age ≥34 wk	97.6	2.4	0
	Attempting vaginal delivery	95.8	3.8	0.4
	Apgar score at 5 min <4 or umbilical cord pH <7.0 or base deficit ≥12 mmol/L	94.0	5.2	0.8
Liveborn, gestational age ≥34 wk, admitted to NICU or special care nursery for respiratory conditions (n = 4641)	Livebirth	99.7	0.1	0.2
	Gestational age ≥34 wk	97.3	2.6	0.1
	Admitted to NICU or special care nursery	97.4	2.2	0.4
Singleton, gestational age ≥37 wk, vertex presentation, clinical diagnosis of shoulder dystocia, no antepartum fetal death, no fetal anomaly (n = 2640)	Singleton	98.8	0.0	1.2
	Gestational age ≥37 wk	98.7	0.2	1.1
	Vertex at admission	94.4	0.5	5.1
	Clinical diagnosis of shoulder dystocia	91.9	7.8	0.3
	No antepartum fetal death	95.9	0.7	3.4
	No fetal anomaly	96.1	0.3	3.6

NICU, neonatal intensive care unit.

Zhang. Contemporary cesarean delivery practice in the US. Am J Obstet Gynecol 2010.

TABLE 2
Description of the study population in comparison to the 2004 US birth cohort

Characteristics	CSL cohort (Nonweighted)	CSL cohort (Weighted)	US birth cohort[a]
No. of women	206,969	3,997,436	4,018,091
Race/ethnicity,[b] %			
Non-Hispanic white	49	57	57
Non-Hispanic black	22	14	14
Hispanics	17	23	23
Asian/Pacific Islander	4	3	5
Other/unknown	8	3	1
Nullipara,[b] %	44	40	40
Multifetal gestation,[b] %	2.3	1.7	1.7
Maternal age, y (mean)	27.6	28.1	27.4
Cesarean delivery, %	29.4	30.5	31.1
Gestational age, wk (mean)	38.2	38.1	38.6
Preterm birth, % (<37 wk)	13.0	14.1	12.8

CSL, The Consortium on Safe Labor.

[a] 2006 National Natality data;[18] [b] These factors plus American College of Obstetricians and Gynecologists district were used to create sample weights.

Zhang. Contemporary cesarean delivery practice in the US. Am J Obstet Gynecol 2010.