Outcomes for Maternal Hospital Care in California, 1999-2001

Office of Statewide Health Planning and Development
Healthcare Information Division

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This report is the Office of Statewide Health Planning and Development's (OSHPD) first public hospital outcomes report on maternal hospital care in California.

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EXECUTIVE SUMMARY: KEY FINDINGS OF THE REPORT ON OUTCOMES FOR MATERNAL HOSPITAL CARE IN CALIFORNIA, 1999-2001

The California Hospital Outcomes Program is an initiative mandated by the State of California, and conducted by the Office of Statewide Health Planning and Development (OSHPD), to develop public reports comparing hospital outcomes for selected conditions and treatments in hospitals throughout the state. Over the last decade, OSHPD has reported hospital mortality rates for heart attack and community-acquired pneumonia. A separate OSHPD program produces reports on hospital and surgeon outcomes for heart bypass surgery (www.oshpd.ca.gov).

This is the first public report that OSHPD has published on maternal hospital care in California. The report is based on analysis of Patient Discharge Data (PDD) records submitted to OSHPD by licensed acute care hospitals, as well as Vital Statistics (VS) birth certificate records submitted to the California Department of Public Health. The delivery patients were admitted to the hospital between October 1999 and November 2001.

The quality of hospital performance for maternity care was assessed by estimating each hospital's rate of two undesirable outcomes: severe perineal lacerations (tears) and postpartum maternal readmissions. Severe perineal lacerations, also described as 3rd or 4th degree, are common but often painful complications of vaginal births. Postpartum maternal readmissions reflect rare but serious complications that occur within 6 weeks after delivery, and require that a woman be readmitted to receive intravenous fluids, powerful antibiotics, surgery, or close monitoring. Both of these quality indicators were risk-adjusted to account for differences in patients' underlying risk of these undesirable outcomes. Each hospital's risk-adjusted rate was then compared with the statewide average, which serves as a benchmark. Hospitals are defined as "better" if their risk-adjusted laceration or readmission rates were statistically significantly lower than the state rate and "worse" if their rates were higher.

To provide more information for women and their families, this report also shows each hospital's vaginal or cesarean delivery rate for two important groups of women: low-risk women who are admitted for their first deliveries, and high-risk women who have had at least one prior cesarean delivery. We focus on these two groups of women because their risk of cesarean delivery is particularly high, and because that risk varies widely across hospitals. By contrast, women who have had prior vaginal deliveries, and no prior cesarean deliveries, tend to have a very low risk of cesarean delivery with subsequent pregnancies, no matter where they go for hospital care. Women with other high risk factors, such as having babies that present feet-first (footling breech) or buttocks-first (breech) instead of head-first, tend to have a very high risk of cesarean delivery no matter where they go.

Key findings from this report include:

- During the study period, 860,588 eligible women were admitted to acute care, nonfederal hospitals in California for delivery of a live baby. Of these women, 4,029 (0.47%) were readmitted to any hospital within 6 weeks after delivery because of a postpartum complication.
- Across the 301 eligible hospitals, the number of eligible deliveries during the study period ranged from 1 to 12,811, and the number of readmissions ranged from 0 to 89. The risk-adjusted readmission rate was 0% for 17 hospitals, 0.01% to 0.49% for 159

hospitals, 0.5% to 0.99% for 110 hospitals, 1.0% to 1.49% for 10 hospitals, and 1.5% or greater for 5 hospitals.

- Sixteen hospitals had significantly fewer readmissions than were expected, based on the characteristics of their patients, whereas fourteen hospitals had significantly more readmissions than were expected.
- During the study period, 651,640 eligible women were admitted to acute care nonfederal hospitals in California and underwent an eligible vaginal delivery. Of these women, 31,331 (4.81%) experienced a third or fourth degree tear.
- Across the 301 eligible hospitals, the number of eligible vaginal deliveries during the study period ranged from 1 to 9,815, and the number of third or fourth degree tears ranged from 0 to 597. The risk-adjusted laceration rate was less than 5% for 180 hospitals, 5% to 10% for 110 hospitals, 10% to 15% for 8 hospitals, and 15% or greater for 3 hospitals.
- Seventy-three hospitals had significantly fewer lacerations than were expected, based on the characteristics of their patients, whereas fifty-six hospitals had significantly more lacerations than were expected.
- There was a weak but consistent association between the risk-adjusted readmission rate (among all deliveries) and the risk-adjusted laceration rate (among vaginal deliveries) at the hospital level. For example, 8 of the 14 hospitals rated as "worse than expected" for postpartum readmissions were also rated as "worse than expected" for tears. Similarly, 8 of the 16 hospitals rated as "better than expected" for postpartum readmissions were also rated as "better than expected" for tears. The concordance between these indicators at the hospital level was surprisingly strong.
- It is critical that all hospitals providing maternal care implement the "best practice" guidelines supported by the medical community. OSHPD's Postpartum Maternal Outcomes Validation Study suggested that many postpartum readmissions could be prevented through careful evaluation of every patient before discharge and prompt attention to early signs of infection. Other clinical and epidemiological studies (summarized below) have suggested that many perineal tears could be prevented by minimizing use of forceps and episiotomy and avoiding certain positions during labor.
- Coding problems do not appear to cause substantial bias in these analyses, but still need to be addressed by California hospitals. For example, about 0.3% of vaginal delivery records and 0.5% of cesarean delivery records had prohibited combinations of 5th digit ICD-9-CM codes, leading to confusion about whether the affected records were antepartum, childbirth, or postpartum records.

Hospitals with “better” and “worse” than expected rates of perineal lacerations are as follows:

Hospitals With “Better” (Lower) Laceration Rates	Hospitals With “Worse” (Higher) Laceration Rates
ALTA BATES SUMMIT MEDICAL CENTER-SUMMIT CAMPUS-HAWTHORNE	ARROWHEAD REGIONAL MEDICAL CENTER
ANTELOPE VALLEY HOSPITAL MEDICAL CENTER	BARSTOW COMMUNITY HOSPITAL
CALIFORNIA PACIFIC MEDICAL CENTER-PACIFIC CAMPUS	BARTON MEMORIAL HOSPITAL
CEDARS SINAI MEDICAL CENTER	COLUSA REGIONAL MEDICAL CENTER
CENTINELA FREEMAN REG MEDICAL CENTER-MEMORIAL CAMPUS	COMMUNITY MEDICAL CENTER - CLOVIS
CITRUS VALLEY MEDICAL CENTER - QV CAMPUS	COMMUNITY MEMORIAL HOSPITAL-SAN BUENAVENTURA
DESERT REGIONAL MEDICAL CENTER	COMMUNITY REGIONAL MEDICAL CENTER-FRESNO
DOCTORS' HOSPITAL MEDICAL CENTER OF MONTCLAIR	DELANO REGIONAL MEDICAL CENTER
DOCTORS HOSPITAL OF MANTECA	GOLETA VALLEY COTTAGE HOSPITAL
DOCTORS MEDICAL CENTER	GOOD SAMARITAN HOSPITAL-SAN JOSE
EAST VALLEY HOSPITAL MEDICAL CENTER	GROSSMONT HOSPITAL
EDEN MEDICAL CENTER	HEMET VALLEY MEDICAL CENTER
EL CENTRO REGIONAL MEDICAL CENTER	KAISER FND HOSPITAL - FONTANA
ELASTAR COMMUNITY HOSPITAL (CLOSED)	KAISER FND HOSPITAL - GEARY S F
EMANUEL MEDICAL CENTER, INC	KAISER FND HOSPITAL - HAYWARD
ENCINO-TARZANA REGIONAL MEDICAL CENTER-TARZANA	KAISER FND HOSPITAL - REHABILITATION CENTER VALLEJO
FOUNTAIN VALLEY RGNL HOSP AND MEDICAL CENTER - EUCLID	KAISER FND HOSPITAL - SACRAMENTO/ROSEVILLE-MORSE
GARDEN GROVE HOSPITAL AND MEDICAL CENTER	KAISER FND HOSPITAL - SANTA CLARA
GARFIELD MEDICAL CENTER	KAISER FND HOSPITAL - SANTA ROSA
GOOD SAMARITAN HOSPITAL-LOS ANGELES	KAISER FND HOSPITAL - SUNSET
GREATER EL MONTE COMMUNITY HOSPITAL	KAWEAH DELTA DISTRICT HOSPITAL
HOAG MEMORIAL HOSPITAL PRESBYTERIAN	KERN MEDICAL CENTER
HOLLYWOOD PRESBYTERIAN MEDICAL CENTER	LITTLE COMPANY OF MARY HOSPITAL
IRVINE REGIONAL HOSPITAL AND MEDICAL CENTER	LOMA LINDA UNIVERSITY MEDICAL CENTER
KAISER FND HOSPITAL - ANAHEIM	LOS ALAMITOS MEDICAL CENTER
KAISER FND HOSPITAL - BELLFLOWER	LOS ROBLES HOSPITAL & MEDICAL CENTER
KAISER FND HOSPITAL - REDWOOD CITY	MARIAN MEDICAL CENTER
KAISER FND HOSPITAL - WEST LA	MERCY HOSPITAL - BAKERSFIELD
KAISER FND HOSPITAL - MANTECA	MERCY HOSPITAL - FOLSOM
LODI MEMORIAL HOSPITAL	MERCY MEDICAL CENTER MERCED-COMMUNITY CAMPUS
LOS ANGELES COUNTY OLIVE VIEW-UCLA MEDICAL CENTER	PLACENTIA LINDA HOSPITAL

LUCILE SALTER PACKARD CHILDREN'S HOSPITAL AT STANFORD	RIVERSIDE COMMUNITY HOSPITAL
MARIN GENERAL HOSPITAL	SAN FRANCISCO GENERAL HOSPITAL
MEMORIAL HOSPITAL OF GARDENA	SANTA BARBARA COTTAGE HOSPITAL
MENDOCINO COAST DISTRICT HOSPITAL	SANTA PAULA MEMORIAL HOSPITAL
MERCY MEDICAL CENTER	SCRIPPS MEMORIAL HOSPITAL - LA JOLLA
MERCY MEDICAL CENTER MERCED-DOMINICAN CAMPUS	SHARP MARY BIRCH HOSPITAL FOR WOMEN
O'CONNOR HOSPITAL - SAN JOSE	SIERRA VIEW DISTRICT HOSPITAL
PACIFIC ALLIANCE MEDICAL CENTER, INC.	SIMI VALLEY HOSPITAL AND HEALTH CARE SVCS-SYCAMORE
PALOMAR MEDICAL CENTER	ST. ELIZABETH COMMUNITY HOSPITAL
PENINSULA MEDICAL CENTER	ST. JOHN'S REGIONAL MEDICAL CENTER
PIONEERS MEMORIAL HOSPITAL	ST. JOSEPH HOSPITAL - ORANGE
POMERADO HOSPITAL	ST. JOSEPH'S MEDICAL CENTER OF STOCKTON
PROVIDENCE SAINT JOSEPH MEDICAL CENTER	ST. JUDE MEDICAL CENTER
REDWOOD MEMORIAL HOSPITAL	ST. MARY REGIONAL MEDICAL CENTER
REGIONAL MEDICAL OF SAN JOSE	SUTTER AMADOR HOSPITAL (CURRENT ID)
ROBERT F. KENNEDY MEDICAL CENTER (CLOSED)	SUTTER AUBURN FAITH HOSPITAL
SALINAS VALLEY MEMORIAL HOSPITAL	TORRANCE MEMORIAL MEDICAL CENTER
SAN GABRIEL VALLEY MEDICAL CENTER	TRI-CITY MEDICAL CENTER
SAN LUIS OBISPO GENERAL HOSPITAL (CLOSED)	TULARE DISTRICT HOSPITAL
SAN RAMON REGIONAL MEDICAL CENTER	UNIVERSITY MEDICAL CENTER
SANTA ANA HOSPITAL MEDICAL CENTER (CLOSED)	UNIVERSITY OF CALIFORNIA DAVIS MEDICAL CENTER
SANTA MONICA - UCLA MEDICAL CENTER	UNIVERSITY OF CALIFORNIA IRVINE MEDICAL CENTER
SCRIPPS MEMORIAL HOSPITAL - ENCINITAS	VERDUGO HILLS HOSPITAL
SEQUOIA HOSPITAL	VICTOR VALLEY COMMUNITY HOSPITAL
SHARP CORONADO HOSPITAL AND HEALTHCARE CENTER	WHITE MEMORIAL MEDICAL CENTER
SIERRA NEVADA MEMORIAL HOSPITAL	
ST. BERNARDINE MEDICAL CENTER	
ST. HELENA HOSPITAL	
ST. JOHN'S PLEASANT VALLEY HOSPITAL	
ST. ROSE HOSPITAL	
SUTTER DAVIS HOSPITAL	
SUTTER DELTA MEDICAL CENTER	
SUTTER LAKESIDE HOSPITAL	
SUTTER MATERNITY AND SURGERY CENTER OF SANTA CRUZ	
SUTTER MEMORIAL HOSPITAL	
TAHOE FOREST HOSPITAL	
UCLA MEDICAL CENTER	
UKIAH VALLEY MEDICAL CENTER/HOSPITAL DRIVE	

VALLEY MEMORIAL HOSPITAL - LIVERMORE	
VALLEY PRESBYTERIAN HOSPITAL	
WATSONVILLE COMMUNITY HOSPITAL	
WEST HILLS HOSPITAL AND MEDICAL CENTER	

Hospitals with “better” and “worse” than expected rates of postpartum maternal readmission are as follows:

Hospitals With “Better” (Lower) Readmission Rates	**Hospitals With “Worse” (Higher) Readmission Rates**
ANTELOPE VALLEY HOSPITAL MEDICAL CENTER	ALTA BATES SUMMIT MEDICAL CENTER-ALTA BATES CAMPUS
DESERT REGIONAL MEDICAL CENTER	DESERT VALLEY HOSPITAL
EL CAMINO HOSPITAL	GOOD SAMARITAN HOSPITAL-SAN JOSE
GARDEN GROVE HOSPITAL AND MEDICAL CENTER	KAISER FND HOSPITAL - SANTA CLARA
HENRY MAYO NEWHALL MEMORIAL HOSPITAL	KAISER FND HOSPITAL – SUNSET
KAISER FND HOSPITAL - FRESNO	LOMA LINDA UNIVERSITY MEDICAL CENTER
MERCY MEDICAL CENTER MERCED-DOMINICAN CAMPUS	MERCY MEDICAL CENTER MT. SHASTA
METHODIST HOSPITAL OF SOUTHERN CALIFORNIA	SAN FRANCISCO GENERAL HOSPITAL
NORTH BAY MEDICAL CENTER	SHARP MARY BIRCH HOSPITAL FOR WOMEN
PROVIDENCE SAINT JOSEPH MEDICAL CENTER	SUTTER ROSEVILLE MEDICAL CENTER
SAN DIMAS COMMUNITY HOSPITAL	UCSF MEDICAL CENTER
SAN GABRIEL VALLEY MEDICAL CENTER	UNIVERSITY OF CALIFORNIA DAVIS MEDICAL CENTER
SANTA BARBARA COTTAGE HOSPITAL	UNIVERSITY OF CALIFORNIA IRVINE MEDICAL CENTER
ST. MARY MEDICAL CENTER	UNIVERSITY OF CALIF-SAN DIEGO MEDICAL CENTER
SUTTER DAVIS HOSPITAL	
SUTTER DELTA MEDICAL CENTER	

This report represents the first systematic effort to report on the quality of care for pregnant women in California hospitals. Although the methods have been developed, refined, and validated over a period of nearly ten years, it is still anticipated that problems will be discovered and opportunities for improvement in future reports will be identified.

Introduction

Childbirth is the most common reason for hospitalization in California, and throughout the United States.

Childbirth was selected as a topic for reporting because – like heart attack and pneumonia — it is common and associated with substantial costs. Unlike heart attack pneumonia, and other conditions OSHPD reports on, it is an anticipated event that women and their families spend months preparing for and anticipating. Childbirth is also a topic of great interest to working families, and their employers, because it is a life-changing event and because complications can cause considerable distress to women, their family members, and their friends. In 2007, women in California expect to have safe, uneventful deliveries, and to return to their usual activities as quickly as possible.

This report has two basic goals. One is to assist healthcare purchasers (employers), payers (insurance companies and managed care organizations), and consumers (patients) with assessing the relative value of healthcare provided to women who are giving birth in California hospitals. Some women and their families may use this information to help select a hospital for childbirth. The second goal is to support and promote quality improvement by hospitals, physicians, nurse midwives, and other health professionals. This report may also be useful to State and county agencies arranging care for program beneficiaries.

Evaluating Hospital Quality

Many expectant mothers and their families want to know: "Which hospital or doctor is most likely to keep me and my baby safe?" Answering this question involves measuring the outcomes of care. Positive outcomes, such as going back to work or school with a healthy baby and no pain, are common but hard to measure. Adverse outcomes, such as complications and readmissions, are much less frequent but are easier to measure from records that hospitals already submit under State law. This report focuses on two outcomes for women who are admitted to a hospital for childbirth.

Perineal lacerations or tears are common complications of vaginal births. If a baby's head is too large for the opening it must go through, or slightly out of position, then that opening sometimes tears. Small tears, called first or second degree by health professionals, are easy to fix and have no long-term consequences. However, larger tears, called third or fourth degree by health professionals, are harder to fix and sometimes lead to long-term problems with bowel control or sexual function.

Research over the past two decades has shown that many (but certainly not all) perineal lacerations can be prevented by avoiding overuse of procedures that increase risk. Episiotomy is a procedure in which the delivering physician or nurse-midwife purposely cuts the vaginal opening to make it larger, to provide more room for the baby's head. This procedure is helpful in some cases, but in other cases, it actually predisposes to larger tears (which are called "extensions"). Forceps and vacuum devices are sometimes used to help pull out a baby whose head is stuck just above the vaginal opening. These procedures may avert some emergency cesarean deliveries, but in other cases, the use of forceps or vacuum leads to third or fourth degree tears. There is more limited evidence that health professionals can do other things to gently stretch the vaginal opening and lower the risk of a larger tear during vaginal delivery.

Based on this research, the Joint Commission has proposed, and the National Quality Forum has endorsed, using third and fourth degree perineal lacerations as a Core Measure of the

quality of care that hospitals provide to pregnant women. Similarly, the US Agency for Healthcare Research and Quality (AHRQ) has recommended monitoring these events as part of a comprehensive set of Patient Safety Indicators (http://qualityindicators.ahrq.gov). Although OSHPD uses the same approach to defining these complications as AHRQ, the method of risk-adjustment in this report is far superior to that embedded in AHRQ's software. This superiority results from the fact that OSHPD can link hospital discharge abstracts and vital statistics records (birth certificates) from each delivery, thereby combining the power of both databases. Birth certificates are not available to AHRQ or used in AHRQ's software, but they contain very valuable information about a woman's medical history and her child's birthweight.

Postpartum maternal readmissions are an unusual but important indicator of complications following both vaginal and cesarean births. There are many reasons why doctors may readmit women to the hospital within 6 weeks after a delivery. For example, some women develop a serious infection of the uterine lining, called postpartum endometritis. Other women develop local infections in their cesarean or episiotomy wound, which can spread and cause significant symptoms. Other women have bleeding that fails to stop, typically because part of the placenta (which nourishes the fetus while it is inside the womb) was retained, or because the muscular lining of the uterus did not contract in the usual way. Finally, a few women experience serious kidney infections or blood clots in their veins after delivery.

Research has shown that many infectious complications can be avoided by giving the right antibiotic in a timely manner when a woman shows signs of infection before delivery, minimizing the number of exams that are done after a woman's membranes rupture, following proper surgical technique, removing bladder catheters quickly, using medications when needed to help the uterus contract, and taking proper care of cesarean and episiotomy wounds.

How the Outcomes Were Measured

Healthcare quality was measured in this report by calculating risk-adjusted laceration rates and risk-adjusted postpartum maternal readmission rates. These rates are useful for comparing quality of care among California hospitals because:

- **They have been risk-adjusted**. Patient age, prenatal risk factors, and selected complications of labor have been used to adjust for differences in patient risk across hospitals. While this set of risk factors is limited to information in the patient discharge data file and the vital statistics (birth certificate) file, it still works fairly well in allowing readers to make apples-to-apples comparisons of how hospitals perform in caring for women who are giving birth. Comparisons of hospitals only on their "observed" (i.e., unadjusted) outcomes would not be appropriate, because different hospitals treat different types of patients. Risk-adjustment allows readers to meaningfully compare a specific hospital's results to both the statewide benchmark and to the results of other hospitals.

- **They have been validated**. A validation study that examined 1,611 medical charts of patients admitted for delivery at 52 randomly selected California hospitals during the mid-1990s showed that third and fourth degree tears are reliably and validly reported to OSHPD. The same study showed that several other types of complications, which were considered for this analysis, are not well reported to OSHPD. Reviewing the medical records for 493 randomly selected postpartum readmissions, it was found that hospitals with high readmission rates also experienced more complications not requiring readmission than did hospitals with low readmission rates. In addition, hospitals with low readmission rates did not achieve their low rates simply by being more selective about

which patients they readmitted after delivery. Although hospitals do not report every relevant risk factor, the study found no evidence that variation in reporting risk factors accounts for the observed variation in adverse outcomes.

The data used in this analysis came from two different sources: hospital patient discharge data collected by OSHPD and vital statistics birth certificate data collected the California Department of Public Health. The hospital data were used to identify women who were admitted for delivery of a child. These data were also used to distinguish vaginal and cesarean deliveries, and to find postpartum readmissions and perineal tears. The vital statistics data, from birth certificates, were used to provide additional information about women's risk factors.

The discharge data contain demographic information, diagnoses, and procedures for all patients admitted to non-federal, acute care hospitals in California. This information was used to select the cases to be analyzed for this report. Specifically, this report focuses on women who were discharged from a nonfederal licensed acute care hospital in California, after giving birth, between January 1, 1999 and November 19, 2001. Patients treated later in 2001 were excluded to avoid missing any postpartum readmissions that occurred within 6 weeks after delivery. Cases with very unusual or serious associated diagnoses, such as cancer or major trauma, were excluded, along with cases that had serious coding errors. Some hospitals were not included in this report because they had too few cases to support analysis of their delivery outcomes. The specific criteria for including and excluding both cases and hospitals are described in Appendix A.

How Risk-Adjustment Was Done

Because some patients, even before they are admitted to the hospital, have an increased risk of complications after delivery, it is important to adjust hospitals' outcome statistics for differences in the risk profiles of their patients. This is a way of "crediting" hospitals that take care of higher risk patients. In other words, to make hospital comparisons fairer, each hospital's outcomes were risk-adjusted based on the presence or absence of various risk factors among its patients.

In this report, a "risk factor" is defined as a characteristic of a patient or a treatment episode that is related to adverse outcomes and cannot be controlled by the hospital. For example, women who have preeclampsia (pregnancy-induced hypertension) or infections before delivery are more likely to require readmission than women without these risk factors. The risk model provides extra "credit" to hospitals with such patients, lowering their risk-adjusted readmission rate. Under the guidance of a panel of clinical experts, which included general obstetricians and perinatologists, family physicians, nurse midwives, and perinatal epidemiologists, risk factors for perineal lacerations and postpartum readmissions were identified. The medical literature was reviewed. In addition, OSHPD's Patient Discharge Dataset was analyzed to help identify the most important risk factors.

A complete list of the risk factors included in the risk-adjustment models, with their associated weights (coefficient estimates), odds ratios (ORs), and confidence intervals, appears in Appendix A. Separate models were constructed for three groups of women: (1) women with no prior deliveries (nulliparous), (2) women with one or more prior cesarean deliveries, and (3) women with prior vaginal deliveries and no prior cesarean deliveries. In this way, different risk factors could be considered for different groups of women.

These risk-adjustment models were used to estimate each woman's probability of having a perineal laceration during vaginal delivery, or being readmitted for a postpartum complication within 6 weeks after either a vaginal or cesarean delivery. At each hospital, the total number of

actual, or “observed,” outcomes was compared to the estimated or “expected” number, based on the sum of these probabilities. The total numbers of observed and expected outcomes were used to calculate risk-adjusted outcome rates for each hospital. Hospitals were rated as “better than expected,”or“ worse than expected” in relationship to the experience of the average hospital in California.

Key Findings

During the study period, 860,588 eligible women were admitted to acute care, nonfederal hospitals in California for delivery of a live baby. Of these women, 4,029 (0.47%) were readmitted to any hospital within 6 weeks after delivery because of a postpartum complication.

Across the 301 eligible hospitals, the number of eligible deliveries during the study period ranged from 1 to 12,811, and the number of readmissions ranged from 0 to 89. The risk-adjusted readmission rate was 0% for 17 hospitals, 0.01% to 0.49% for 159 hospitals, 0.5% to 0.99% for 110 hospitals, 1.0% to 1.49% for 10 hospitals, and 1.5% or greater for 5 hospitals. Table 1 shows that the observed and risk-adjusted readmission rates were quite consistent across low-volume, medium-volume, and high-volume hospitals.

Table 1: Summary of observed and risk-adjusted postpartum maternal readmission rates across hospital volume strata

Quintile	Range of hospital volume	Number of hospitals	Number of patients	Number of readmissions	Observed readmission rate	Risk-adjusted readmission rate
1	1-624	61	22344	115	0.51%	0.51%
2	626-1190	60	71761	377	0.53%	0.51%
3	1209-2262	60	135429	566	0.42%	0.42%
4	2263-3613	60	218712	1005	0.46%	0.45%
5	3681-9815	60	412342	1966	0.48%	0.48%

Sixteen hospitals had significantly fewer readmissions than were expected, based on the characteristics of their patients, whereas fourteen hospitals had significantly more readmissions than were expected. The 16 low-readmission hospitals had risk-adjusted readmission rates of 0.07% to 0.28%, with an overall total of 99 observed readmissions (0.18%), 253 expected readmissions (0.46%), and a risk-adjusted readmission rate of 0.18%. The 14 high-readmission hospitals had risk-adjusted readmission rates of 0.61% to 2.29%, with an overall total of 597 observed readmissions (0.86%), 345 expected readmissions (0.50%), and a risk-adjusted readmission rate of 0.81%. Therefore, women who gave birth at high-readmission hospitals had 4.4 times the risk of needing readmission after delivery, after adjusting for other factors, than women who give birth at low-readmission hospitals.

During the study period, 651,640 eligible women were admitted to acute care nonfederal hospitals in California and underwent an eligible vaginal delivery. Of these women, 31,331 (4.81%) experienced a third or fourth degree tear.

Across the 301 eligible hospitals, the number of eligible vaginal deliveries during the study period ranged from 1 to 9,815, and the number of third or fourth degree tears ranged from 0 to 597. The risk-adjusted laceration rate was less than 5% for 180 hospitals, 5% to 10% for 110 hospitals, 10% to 15% for 8 hospitals, and 15% or greater for 3 hospitals. Table 2 shows that

the observed and risk-adjusted laceration rates were quite consistent across low-volume, medium-volume, and high-volume hospitals.

Table 2: Summary of observed and risk-adjusted perineal laceration rates across hospital volume strata

Quintile	Range of hospital volume	Number of hospitals	Number of patients	Number of lacerations	Observed laceration rate	Risk-adjusted laceration rate
1	1-624	61	17033	657	3.86%	4.39%
2	626-1190	60	53931	2301	4.27%	5.27%
3	1209-2262	60	103407	4288	4.15%	4.38%
4	2263-3613	60	164856	7375	4.46%	4.78%
5	3681-9815	60	312413	16728	5.35%	4.91%

Seventy-three hospitals had significantly fewer lacerations than were expected, based on the characteristics of their patients, whereas fifty-six hospitals had significantly more lacerations than were expected. The 73 low-readmission hospitals had risk-adjusted laceration rates of 0.2% to 4.7%, with an overall total of 6,538 observed lacerations (3.6%), 9,544 expected lacerations (5.2%), and a risk-adjusted laceration rate of 3.3%. The 56 high-laceration hospitals had risk-adjusted laceration rates of 5.5% to 20.2%, with an overall total of 11,036 observed lacerations (6.7%), 7,849 expected lacerations (4.8%), and a risk-adjusted laceration rate of 6.8%. Therefore, women who gave birth at high-laceration hospitals had 2.1 times the risk of suffering a tear, after adjusting for other factors, as women who gave birth at low-readmission hospitals.

There was a weak but consistent association between the risk-adjusted readmission rate (among all deliveries) and the risk-adjusted laceration rate (among vaginal deliveries) at the hospital level. For example, 8 of the 14 hospitals rated as “worse than expected” for postpartum readmissions were also rated as “worse than expected” for tears. Similarly, 8 of the 16 hospitals rated as “better than expected” for postpartum readmissions were also rated as “better than expected” for tears. The concordance between these indicators at the hospital level was surprisingly strong, as shown in Table 3:

Table 3: Comparing California hospitals on risk-adjusted readmission and risk-adjusted laceration rates

Readmissions	Lacerations			
	Worse than expected	Neither	Better than expected	Total
Worse than expected	8	6	0	14
Neither	47	159	65	271
Better than expected	1	7	8	16
Total	56	172	73	301

Calculation of Risk-Adjusted Outcome Rates

Risk-adjusted outcome measures are calculated in three steps (explained in greater detail in Appendix A):

- First, the actual number of severe perineal lacerations, or postpartum maternal readmissions within 6 weeks, is divided by the total number of eligible cases in the hospital to obtain the observed laceration or readmission rate.
- Second, each patient's probability of laceration and probability of readmission are calculated using the risk adjustment models. These probabilities are combined to obtain the expected number of lacerations and readmissions for each hospital. The expected number of lacerations or readmissions is divided by the actual number of cases to obtain the expected laceration or readmission rate.
- Third, the observed rate is divided by the expected rate. This ratio is then multiplied by the statewide rate for that outcome to obtain the hospital's risk-adjusted laceration or readmission rate.
- Fourth, a statistical test is applied to determine whether the hospital's risk-adjusted rate is statistically significantly different from the state average.

If a hospital's observed rate is greater than the expected rate, the hospital had more adverse events than expected, given the level of risk in its patients. In this case the ratio of observed to expected would be greater than 1.0; multiplying this number times the statewide rate would result in a number greater than the statewide rate. That is, the risk-adjusted laceration or readmission rate is higher than the statewide rate.

On the other hand, if a hospital's observed rate is lower than the expected, then the ratio of these is less than 1.0. Multiplying this number times the statewide rate results in a number lower than the statewide rate. For this hospital, the risk-adjusted laceration or readmission rate is lower than the statewide rate.

Whether the hospital's outcome is statistically significant or not depends on three factors: the number of eligible patients at the hospital, the size of the gap between the hospital's risk-adjusted outcome rate and the statewide benchmark, and the confidence level selected for the test. For this report, a conservative 99% level of confidence was used (indicated as $p < .01$). With this level of confidence, there is just one chance in 100 of making an error about whether a hospital's outcome rate is truly greater than the statewide benchmark (on the high side) or lower than the statewide benchmark (on the low side).[1]

It is important to remember that size matters. For hospitals with large numbers of patients the statistical confidence interval will be narrow, so moderate or even small-sized gaps may be significantly different from the statewide rate. For small hospitals, the confidence interval is wider. This means that a risk-adjusted rate must be much larger or much smaller than the statewide rate to be found significantly different.

Some hospitals were excluded from this report because they only had a small number of deliveries or because they did not have active maternity programs. These hospitals, identified in Appendix A, were not rated as significantly higher or significantly lower than the statewide average, and are not shown in Charts 1 and 2.

[1] Luft HS, Brown BW Jr. Calculating the probability of rare events: Why settle for an approximation? Health Services Research 1993; 28:419-439.

Hospital Risk-Adjusted Outcome Rates for Delivery Patients Compared to Statewide Rate

Chart 1 shows the risk-adjusted perineal laceration rate for each hospital included in the analysis. The hospitals are listed in alphabetical order, by county. The black solid circle (●) on a row's horizontal bar represents a hospital's risk-adjusted laceration rate and the horizontal bar itself represents its 98% confidence interval. If this bar crosses the dashed vertical line placed at 4.83% (representing the statewide laceration rate), then the hospital's adjusted rate is "as expected." Otherwise, it is considered significantly different from the statewide rate.

Symbols on the chart indicate the following:

- Hospitals with significantly lower laceration rates have a "better" quality rating and are identified with a plus sign (+).
- Hospitals with significantly higher laceration rates have a "worse" quality rating and are identified with a minus sign (-).
- Hospitals that were not significantly different than expected are not assigned a symbol and have an "as expected" quality rating for maternity care.

Chart 2 shows the risk-adjusted readmission rate for each hospital included in the analysis. The hospitals are listed in alphabetical order, by county. The black solid circle (●) on a row's horizontal bar represents a hospital's risk-adjusted readmission rate and the horizontal bar itself represents its 98% confidence interval. If this bar crosses the dashed vertical line placed at 0.47% (representing the statewide readmission rate) then the hospital's adjusted rate is "as expected." Otherwise, it is considered significantly different from the statewide rate.

Symbols on the chart indicate the following:

- Hospitals with significantly lower readmission rates have a "better" quality rating and are identified with a plus sign (+).
- Hospitals with significantly higher readmission rates have a "worse" quality rating and are identified with a minus sign (-).
- Hospitals that were not significantly different than expected are not assigned a symbol and have an "as expected" quality rating for maternity care.

Appendix A: Technical Notes

Overview

This Technical Appendix summarizes how the data were analyzed for this report. It is divided into the following sections:

1. **Data Sources** describes the data that were used
2. **Selection of Hospitals** describes which hospitals were eligible for study, which hospitals were excluded, and why they were excluded.
3. **Selection of Patients** describes which patients were eligible for study, which patients were excluded, and why they were excluded.
4. **Linking Hospitalization Files** describes how records of multiple hospitalizations for the same woman were linked to exclude invalid cases, to identify postpartum maternal readmissions, and to enhance ascertainment of risk factors.
5. **Linking Vital Statistics Files** describes how delivery records were linked with birth certificate records to build a more complete data set for analyses of risk-adjusted hospital outcomes.
6. **Selection and Measurement of Outcomes** describes how and why perineal lacerations and postpartum maternal readmissions were selected as the two major adverse outcomes for public reporting. A summary of relevant clinical literature about risk factors for these outcomes is also provided.
7. **Risk Factors in the Model** describes how risk factors for these adverse outcomes were defined and identified. Tables showing the distribution of these risk factors across all California hospitals are provided.
8. **Procedure for Developing Risk-Adjustment Models** describes how risk-adjustment models were designed, estimated, and internally validated. Tables showing the coefficient estimates from these risk-adjustment models are provided.
9. **Calculation of Hospital Outcome Measures** describes how the risk-adjustment models were applied to estimate risk-adjusted hospitals outcomes and to classify hospital performance.

Data Sources

The primary data source for this report was the Patient Discharge Data (PDD) collected by OSHPD. The PDD consists of administrative abstracts of the medical records of all patients discharged from all non-federal acute care hospitals in California. Each patient discharge abstract includes a principal diagnosis and principal procedure, plus as many as 24 other diagnoses and 20 other procedures. For each diagnosis, there is a flag to indicate whether the diagnosis was a condition present at admission (CPAA). Each record also includes the patient's Social Security Number, demographic characteristics (e.g., age, gender, race, and ethnicity), and information about the hospitalization episode (e.g., dates of admission and discharge, presence of a DNR order, source of admission, destination of the discharge, and expected source of payment). This report focuses on maternal hospitalizations, which represent inpatient records of women who underwent childbirth in an acute care hospital.

These Patient Discharge Data were linked with birth certificate records from the California Department of Public Health's vital statistics data system, using probabilistic methods that are described in more detail below. Birth certificates include more detailed information about the mother's sociodemographic characteristics (e.g., usual occupation and industry, date last worked, place of birth, and educational attainment), historical information about the course of

the current pregnancy (e.g., date last normal menses began, date of first and last prenatal care visit, number of prenatal visits, pre-pregnancy weight, maternal smoking, pregnancy complications) and prior pregnancies (e.g., number and outcome of prior pregnancies, date of last live birth, prior cesarean deliveries), and circumstances surrounding the delivery (e.g., birth weight, estimated gestational age, Apgar scores at 1, 5, and 10 minutes, place of birth, method of delivery, multiple gestation with sequence of delivery, date and hour of birth, complications of labor and delivery). This information is typically collected by hospital staff shortly after delivery, by reviewing medical records and interviewing parents.

Selection of Hospitals

All acute care hospitals reporting discharge information to OSHPD were eligible for inclusion. Hospitals operated by the US Department of Veterans Affairs, Indian Health Service, or Department of Defense do not report data to OSHPD and therefore could not be included.

If a hospital moved or was renamed during the report period but retained its facility identification number, all eligible cases were assigned to the new hospital location or name. Thirteen hospitals closed between the beginning of the study period and the end of 2005; cases from these hospitals were included in the analyses reported herein but no hospital-level outcome statistics were generated. These 13 hospitals are listed below:

1. Lassen Community Hospital Inc., 560 Hospital Lane, Susanville, CA 96130, Closed 04/22/2003
2. Granada Hills Community Hospital, 10445 Balboa Blvd., Granada Hills, CA 91344, Closed 04/30/2004
3. Robert F. Kennedy Medical Center, 4500 116th St., Hawthorne, CA 90250, Closed 12/09/2004
4. Elastar Community Hospital, 319 North Humphreys Ave., Los Angeles, CA 90022, Closed 08/19/2004
5. Santa Teresita Hospital, 819 Buena Vista St., Duarte, CA 91010-1703, Closed 06/30/2004
6. St. Luke Medical Center, 2632 East Washington Blvd., Pasadena, CA 91107, Closed 06/30/2003
7. Northridge Hospital Medical Center - Sherman Way, 14500 Sherman Circle, Van Nuys, CA 91405, Closed 11/17/2004
8. Orange Co. Community Hospital - Buena Park, 6850 Lincoln Ave., Buena Park, CA 90620, Closed 04/06/2003
9. Santa Ana Hospital Medical Center Inc., 1901 North Fairview St., Santa Ana, CA 92706, Closed 09/01/2003
10. San Luis Obispo General Hospital 2180 Johnson St., San Luis Obispo, CA 9340, Closed 06/19/2003
11. St. Francis Medical Center of Santa Barbara, 601 E. Micheltorena St., Santa Barbara, CA 93103, Closed 06/18/2003
12. San Jose Medical Center, 675 East Santa Clara St., San Jose, CA 95112, Closed 12/09/2004
13. Lindsay District Hospital, 740 North Sequoia Ave., Lindsay, CA 93247, Closed 12/30/2001

In addition, two hospitals moved and changed their facility identification numbers during the study period. Data submitted by these hospitals before their move dates were reassigned to the new hospital location and identification numbers:

1. St. Louise Regional Hospital-Morgan Hill, Moved 9/1999 and changed name to St. Louise Regional Hospital, Gilroy, CA 95020
2. Sutter Amador Hospital, Moved 4/2000 (without change of name) to 200 Mission Blvd., Jackson, CA 95642

Several hospitals had very few deliveries during the study period. It is likely that these hospitals do not actually provide obstetric services. The few deliveries reported from these hospitals could have been miscoded antepartum or postpartum hospitalizations, deliveries performed prior to admission (e.g., at a different hospital, in an ambulance, or in a parking lot), or unanticipated deliveries. It would have been inappropriate to include these hospitals in this public report, because they do not typically provide obstetric services.

We initially attempted to exclude these hospitals by using OSHPD's 1999-2001 Annual Reports of Hospitals (available online at http://www.oshpd.ca.gov/HQAD/Hospital/hosputil.htm) to identify facilities with no licensed perinatal beds and no labor/delivery/recovery (LDR) or labor/delivery/recovery/postpartum (LDRP) beds on December 31 of that year. However, this approach was unsuccessful because two hospitals with licensed perinatal beds (in all study years) had fewer than three deliveries during the entire study period, and nine hospitals with no qualifying beds had 60 or more deliveries during the study period.

Therefore, we instead adopted numerical criteria based on analyses of statistical power, and excluded hospitals that failed to meet these criteria from public reporting of hospital outcomes (but not from statewide analyses). The hospitals listed in Table A.1 had too few vaginal delivery patients to be rated on perineal lacerations. No judgment can be made on the quality of care provided by these hospitals with respect to perineal lacerations. The volume threshold of 35 eligible cases was selected to ensure at least 60% power to label a hospital as a "better" outlier if it had zero perineal lacerations and an expected laceration rate equal to the state average. In other words, for all of the hospitals NOT listed here, the probability of correctly labeling a hospital with zero lacerations as a "better" outlier (assuming that it really provides better-than-average care) is at least 60%. The two hospitals designated with asterisks had no licensed perinatal beds or LDR/LDRP (alternative birthing center) beds during the study period.

Table A.1: Hospitals excluded from reporting on perineal lacerations

OSHPD ID number	Hospital	Number of perineal lacerations	Number of eligible vaginal deliveries	Observed perineal laceration rate (%)
100697	COALINGA REGIONAL MEDICAL CENTER	0	2	0
240853	DOS PALOS MEM. HOSPITAL*	0	1	0
321016	SENECA HEALTHCARE DISTRICT	4	32	12.5
370694	SHARP MEMORIAL HOSPITAL	0	1	0
434020	ST. LOUISE REGIONAL HOSPITAL-MORGAN HILL	0	32	0
250955	SURPRISE VALLEY COMMUNITY HOSPITAL*	0	2	0

The hospitals listed in Table A.2 had too few deliveries to be rated on postpartum maternal readmissions. No judgment can be made on the quality of care provided by these hospitals with respect to readmission. The volume threshold of 355 eligible cases was selected to ensure at least 60% power to label a hospital as a "better" outlier if it had zero readmissions and an expected readmission rate equal to the state average. In other words, for all of the hospitals NOT listed here, the probability of correctly labeling a hospital with zero postpartum maternal readmissions lacerations as a "better" outlier (assuming that it really provides better-than-average care) is at least 60%. The four hospitals designated with asterisks had no licensed perinatal beds or LDR/LDRP (alternative birthing center) beds during the study period.

Table A.2: Hospitals excluded from reporting on postpartum readmissions

OSHPD ID number	Hospital	Number of postpartum maternal readmissions	Number of eligible deliveries	Observed postpartum maternal readmission rate (%)
010735	ALAMEDA HOSPITAL	2	337	0.59
100791	CENTRAL VALLEY ORTHOPEDIC AND SPINE INSTITUTE	1	246	0.41
100697	COALINGA REGIONAL MEDICAL CENTER	0	2	0
361458	COLORADO RIVER MEDICAL CENTER	1	187	0.53
060870	COLUSA REGIONAL MEDICAL CENTER	1	168	0.6
190538	COMMUNITY AND MISSION HOSPITAL OF HNTG PARK-FLORENCE	0	88	0
190857	DOCTORS HOSPITAL OF WEST COVINA, INC	0	65	0
240853	DOS PALOS MEMORIAL HOSPITAL*	0	1	0
474007	FAIRCHILD MEDICAL CENTER	3	308	0.97
160725	HANFORD COMMUNITY MEDICAL CENTER*	0	1	0
490964	HEALDSBURG DISTRICT HOSPITAL	0	166	0
180919	LASSEN COMMUNITY HOSPITAL (CLOSED)	2	309	0.65
540746	LINDSAY DISTRICT HOSPITAL (CLOSED)	1	128	0.78
260011	MAMMOTH HOSPITAL	0	79	0
050932	MARK TWAIN ST. JOSEPH'S HOSPITAL	1	73	1.37
450936	MAYERS MEMORIAL HOSPITAL	3	153	1.96
470871	MERCY MEDICAL CENTER MT. SHASTA	5	223	2.24
250956	MODOC MEDICAL CENTER	1	59	1.69
361266	MOUNTAINS COMMUNITY HOSPITAL	2	204	0.98
560501	OJAI VALLEY COMMUNITY HOSPITAL	2	54	3.7
320986	PLUMAS DISTRICT HOSPITAL	0	118	0
171049	REDBUD COMMUNITY HOSPITAL	2	186	1.08
301325	SADDLEBACK MEMORIAL MEDICAL CENTER - SAN CLEMENTE	1	122	0.82
190691	SANTA TERESITA HOSPITAL	0	339	0

OSHPD ID number	Hospital	Number of postpartum maternal readmissions	Number of eligible deliveries	Observed postpartum maternal readmission rate (%)
	(CLOSED)			
321016	SENECA HEALTHCARE DISTRICT	1	55	1.82
370694	SHARP MEMORIAL HOSPITAL	0	1	0
450940	SHASTA REGIONAL MEDICAL CENTER	0	138	0
491076	SONOMA VALLEY HOSPITAL	2	336	0.6
434020	ST. LOUISE REGIONAL HOSPITAL-MORGAN HILL (PREVIOUS ID)	0	44	0
430905	STANFORD HOSPITAL*	0	2	0
250955	SURPRISE VALLEY COMMUNITY HOSPITAL*	0	2	0
034002	SUTTER AMADOR HOSPITAL	2	267	0.75
030786	SUTTER AMADOR HOSPITAL (PREVIOUS ID)	0	96	0
531059	TRINITY HOSPITAL	1	76	1.32
301379	WEST ANAHEIM MEDICAL CENTER	0	117	0

Selection of Patients

Inclusion and exclusion criteria were developed after careful review of the medical literature and extensive discussions with an expert panel. This panel included two family physicians involved in obstetric practice, three perinatologists with specialized training in high-risk obstetrics, three general obstetrician-gynecologists, two nurse midwives, and a perinatal nurse specialist. Diagnostic and procedure data from the patient discharge abstract were used to identify all deliveries and to exclude atypical or questionable cases that might cluster at certain hospitals. Many of these exclusions were necessitated by inconsistencies that were discovered in analyzing linked discharge abstracts for selected women. These inclusion and exclusion criteria are described in detail in the following subsections.

Inclusion criteria

Delivery cases were identified by reviewing discharge abstracts from all acute care hospitals in California that report data to OSHPD. Discharge abstracts that were identified as coming from a non-acute level of care (e.g., skilled nursing, rehabilitation) were not reviewed. Cases selected for the delivery study were required to meet all three of the inclusion criteria listed below.

1. **A pregnancy-related principal or secondary diagnosis of 640-676 with a fifth digit of 1 ("delivered, with or without mention of antepartum condition") or 2 ("delivered, with mention of postpartum complication"); or 650 ("delivery in a completely normal case"), which has no associated fifth digit**.

Hospitals are not required to use a procedure code for a completely normal vaginal delivery. For this reason, deliveries must be identified using diagnosis codes rather than procedure codes. To capture all deliveries, regardless of the original reason for admission, any case with a principal or secondary diagnosis indicating delivery was selected.

2. **Age at discharge between 10 years and 55 years (inclusive).**

Deliveries outside this age range were not included because they are physiologically implausible. Although deliveries among young teenagers are unusual, they do occasionally occur. Age is an essential variable in all risk modeling for maternal outcomes.

3. **Discharge date between January 1, 1999 and November 19, 2001 (inclusive).**

Patients discharged after November 19 were excluded to avoid missing any postpartum readmissions that occurred within 6 weeks after delivery.[2] Discharge records for discharges occurring after December 31, 2001, were not yet available when this study was first designed. The discharge date was used to define this time window, instead of the infant's birth date, because the sample had to be identified before the vital statistics linkage was performed.

Dating deliveries and excluding inappropriate delivery dates

To select the final sample, it was necessary to estimate the actual date of each delivery. This date was important for defining the postpartum follow-up period. Because hospitals are not required to use a procedure code for a normal delivery, the date of delivery was unreported in about 38% of all vaginal deliveries.

To resolve this problem, a list of procedures generally associated with delivery was developed. These procedures almost invariably are performed in the delivery suite, just before, during, or just after the delivery itself. The date of delivery then was inferred from these associated procedure dates. If multiple procedures were performed on the same woman on different dates, the earliest date was chosen. This list of associated procedures included:

- 72.xx Forceps, vacuum, and breech delivery
- 73.5x Manually assisted delivery
- 73.6 Episiotomy
- 73.8 Operations on fetus to facilitate delivery
- 73.9x Other operations assisting delivery
- 74.x Cesarean section and removal of fetus

Cesarean delivery cases in which all of the Cesarean procedure codes (74.0, 74.1, 74.2, 74.4, 74.91, 74.99) either lacked a corresponding date or had a date prior to the date of admission were excluded. Most of these cases probably had miscoded dates, although a few might actually have been postpartum admissions after cesarean deliveries that occurred elsewhere. Because the number of such cases was quite small, they were excluded from the study.

Vaginal delivery cases that were still missing a delivery date after the procedure described above, or had a delivery date prior to the date of admission, were reassigned a delivery date equal to the date of admission. There were too many such cases to exclude, and nearly all appeared to have been normal deliveries that probably occurred within 24 hours of admission. All but 32 of a sample of 160 cases that were originally assigned a delivery date before the date of admission had secondary diagnosis codes (V27.x, "outcome of delivery") indicating that the delivery occurred in the reporting facility.

Cases with reported or reassigned vaginal or cesarean delivery dates before September 30, 1999 were then excluded to provide a full 273-day (9 month) period before delivery to ascertain antepartum hospitalizations. These antepartum records provided important information about risk factors that were not always reported on the delivery abstract.

[2] In future reports, OSHPD may elect to include cases through the end of the study period in analyses and reporting of perineal lacerations.

Identification of Cesarean deliveries

The subset of Cesarean deliveries then was identified in the following manner:

1. **Any case with a principal or other procedure of 74.0 (classical cesarean section), 74.1 (low cervical cesarean section), 74.2 (extraperitoneal cesarean section), 74.4 (cesarean section of other specified type), or 74.99 (other cesarean section of unspecified type) was classified as a cesarean delivery.**

The study was not limited to low cervical Cesarean "sections" (74.1) because the Clinical Advisory Panel felt that the classical approach generally has similar short-term outcomes, and because 74.4 and 74.99 were used primarily by several hospitals that privately acknowledged miscoding low cervical "sections."

2. **Any case with a principal or other procedure of 74.91 (hysterotomy to terminate pregnancy) and an associated V code in any diagnosis field indicating a live birth was also classified as a cesarean delivery.**

The live birth codes include V27.0 (single liveborn), V27.2 (twins, both liveborn), V27.3 (twins, one liveborn and one stillborn), V27.5 (other multiple birth, all liveborn), or V27.6 (other multiple birth, some liveborn). A special criterion for ICD-9 procedure code 74.91 was necessary because this procedure code is assigned when a woman is admitted for termination of pregnancy but unexpectedly delivers a living (premature) infant.

3. **Any case with a principal or other procedure of 74.3 (removal of intraperitoneal embryo) or 74.91 (hysterotomy to terminate pregnancy) that had not been assigned to the cesarean section sample in the two preceding steps was excluded; all remaining cases (e.g., those without any procedure code of 74.xx) were classified by default as vaginal deliveries.**

A Cesarean delivery to remove an intraperitoneal embryo or terminate a pregnancy is not directly comparable to a Cesarean delivery of an intrauterine pregnancy.

Exclusion Criteria (before linkage)

According to OSHPD's reabstracting study, a small number of cases classified through the above algorithm as vaginal deliveries may have been delivered before coming to the hospital or may not have been delivered at all. Some of these suspected miscodes and other problematic cases were excluded from the analysis of delivery outcomes. The first five exclusion criteria were applied to unlinked delivery records; additional exclusions (described later) were applied after linkage of multiple records for the same individual.

1. **A principal or secondary diagnosis of malignant neoplasm of any type (141.x-172.x, 174.x-208.x), except non-melanoma neoplasms of the skin or lip.**

These conditions are quite rare and often require chemotherapy or radiation therapy during the same hospitalization. Indeed, these patients often have early induction of labor or cesarean delivery so they can begin receiving therapy for malignancy.

2. **A principal or secondary diagnosis of Cesarean delivery without mention of indication (669.7x) among cases classified as vaginal deliveries.**

These cases suffer from ambiguity regarding the mode of delivery; the diagnosis codes suggest Cesarean delivery, but the lack of Cesarean procedure codes suggests vaginal delivery. Most such cases had other characteristics consistent with Cesarean delivery (e.g., postoperative length of stay, total charges). Although several other diagnosis and procedure codes raised similar questions about the actual mode of delivery (e.g., 659.0x, 659.1x, 660.6x, 660.7x, 73.3), virtually none of these cases had other characteristics consistent with Cesarean delivery. Therefore, only cases with 669.7x were excluded.

3. **A principal diagnosis of postpartum care (V24.x), hydatidiform mole (630), other abnormal product of conception (631), or ectopic pregnancy (633.x).**

The principal diagnosis is "the condition established, after study, to be chiefly responsible for occasioning the admission of the patient to the hospital for care." A principal diagnosis of postpartum care suggests that the patient actually delivered before admission. This impression was confirmed by the fact that 63 of a previous sample of 140 such cases had a procedure code for laceration repair (75.69) or placental extraction (75.4) but only 6 had one of the delivery procedure codes listed above.

A principal diagnosis of hydatidiform mole, other abnormal product of conception, or ectopic pregnancy suggests that the patient was admitted with a markedly abnormal pregnancy. Hydatidiform mole is a neoplasm involving fetal chorionic tissue that invades the female host. Ectopic pregnancies result from fertilized ova that implant outside the uterine cavity. The most common locations are in the fallopian tube, on the ovary, or on the peritoneum. All of these principal diagnoses are generally incompatible with live birth at or near term. Most cases with these principal diagnoses had procedure codes consistent with molar or ectopic pregnancy (as opposed to normal delivery).

These exclusions were necessary because of the inappropriate use of delivery diagnosis codes (640-648 or 651-676 with a fifth digit of 1 or 2). According to ICD-9-CM coding guidelines, all diagnoses of 640-648 or 651-676 should have a fifth digit of 0 among patients admitted for molar, other blighted, or ectopic pregnancies. OSHPD recently implemented editing criteria to identify such coding errors and to give hospitals the opportunity to correct their data before public release.

Note that cases with a **secondary** diagnosis of hydatidiform mole or ectopic pregnancy were not excluded. All but one of these cases had delivery procedure codes and other characteristics suggesting that the hydatidiform mole or ectopic pregnancy actually was related to a prior pregnancy, not the current pregnancy. Cases with a **secondary** diagnosis of "other abnormal product of conception" were not excluded because this sequence is used to describe a "blighted ovum" with an otherwise successful multiple gestation. Likewise, cases with a **secondary** diagnosis of postpartum care were not excluded because this sequence is compatible with in-hospital delivery.

4. **A principal or secondary diagnosis of missed abortion (632) or other pregnancy with abortive outcome (634.xx-639.x).**

The expulsion of a fetus that weighs less than 500 grams and has an estimated gestational age of less than 22 weeks is defined as an abortion. Abortions may be either spontaneous (e.g., miscarriage), induced, or missed (e.g., retention of a dead fetus). Abortions and deliveries are mutually exclusive. When a discharge abstract had a diagnosis code indicating delivery (as defined in the inclusion criteria above) and a separate diagnosis code indicating abortion, it could not be determined whether the patient actually had an abortion or a delivery.

5. **A principal or secondary diagnosis of significant traumatic injury (800.x-839.x, 850.x-904.x, 925.x-929.x, 940.x-958.x) or fetal death (656.4x, V27.1, V27.3-V27.4, V27.6-V27.7), with an external cause-of-injury (E) code indicating a non-iatrogenic cause (E800-E848, E880-E899, E905-E909, E916-E926, E928, E950-E958, E960-E966, E968, E970-E976, E980-E988) and no other E codes suggesting iatrogenic injury (E849.7, E870-E876).**

Pregnant women with significant injuries are much more likely to be admitted to designated trauma centers than to other hospitals in the same community. Abdominopelvic trauma may stimulate premature labor or even cause fetal death. These women were very high-risk, but it was impossible to model this additional risk adequately in the risk-adjustment process. To allow delivery outcomes at trauma centers to be compared with those at other hospitals, pregnant women with significant, non-iatrogenic injuries were excluded. Women who suffered only minor injuries such as sprains, superficial injuries, and contusions were not excluded. Women whose injuries were attributed to medical or surgical care, or occurred in a hospital or other residential institution, were not excluded because these injuries likely occurred after admission. Table A.3 summarizes these pre-linkage exclusions.

Table A.3: Cases excluded before linkage

Reason for Exclusion	number	%
Cesarean delivery in which all Cesarean procedure codes (74.0-74.2, 74.4, 74.91, 74.99) either lacked a corresponding date or had a date prior to the date of admission	1610	0.128
Reported or reassigned vaginal or cesarean delivery date outside the study period (e.g., too early to identify antenatal hospitalization)	385581	30.614
Principal or other procedure of 74.3 (removal of intraperitoneal embryo) or 74.91 (hysterotomy to terminate pregnancy) without evidence of cesarean delivery	17	0.001
Principal or secondary diagnosis of malignant neoplasm of any type, except non-melanoma neoplasms of the skin and lip	439	0.035
Principal or secondary diagnosis of cesarean delivery without mention of indication among cases classified as vaginal deliveries		
Principal or secondary diagnosis of V24.x (postpartum care), 630 (hydatidiform mole), 631 (other abnormal product of conception), or 633.x (ectopic pregnancy)	860	0.068
Principal or secondary diagnosis of 632 (missed abortion), 634.xx-639.xx (other pregnancy with abortive outcome)		
Principal or secondary diagnosis of significant traumatic injury or fetal death (see text), with an external cause of injury code indicating a non-iatrogenic cause	127	0.010

Linking Hospitalization Files

Linking hospitalization records is important for several reasons. First, linkages with subsequent records identified one of the outcomes of interest (e.g., readmission). Second, linkages made it possible to identify improbable deliveries, based on the juxtaposition of certain combinations of records (as described below). Third, linkages provided important information about clinical risk factors that may not have been coded on the delivery record. The purpose of this section is to describe the linkage methods used and to discuss the implications of linkage problems. The most prevalent and serious linkage problem was that about 20% of delivery records had missing or

invalid social security numbers (SSNs). It was essentially impossible to find readmissions for these patients, so they were excluded from the readmissions analysis.

The goal of the linkage process was to identify relevant hospital discharge records, to order them temporally and logically, and then to create a linked single-record analysis file summarizing information from all related records for each patient. The main steps in linking hospitalization records were to: (1) identify records that met initial selection criteria, (2) find all additional records with linkage potential, (3) delete duplicate records and re-sequence record sets, (4) order records in the period around the index admission, and (5) create a linked single-record analysis file (i.e., one line of data per patient).

1. **Identify records that met initial selection criteria**

The first step in record linkage was to create a *condition file* containing all records that (1) met preliminary selection criteria and (2) were within the time window used to select cases. At this point, records in the condition files were only *candidates* for study.

2. Find all additional records with linkage potential

The goal of this step was to find any additional candidate records within the study frame, starting nine months before the delivery date and ending six weeks after the delivery date. To start this search, the condition file was divided into two subfiles: one contained records with an SSN, and the other contained records lacking an SSN. A lookup file was created from the condition sub file with SSNs, which contained the minimum information needed to identify a record as being a potential match (i.e., the SSN, date of birth, and all admission and delivery dates found for that SSN). When more than one date of birth was associated with the same SSN, the SSN was reset to missing. Three possible explanations for this scenario included: (1) the same SSN was used or reported by more than one woman; (2) a hospital incorrectly ascribed the same SSN to multiple patients; or (3) multiple dates of birth were incorrectly reported or entered for the same patient.

The resulting lookup file was used to search for candidate records that matched exactly on SSN, birth date and female gender, and were in the appropriate time frame relative to the dates of delivery. Linkage was not performed when a delivery record had a missing or invalid SSN, due to concern about the relatively high risk of "false positive" linkage given the narrow age range within which most deliveries occur and the high volume of deliveries in California (about 500,000 annually and as many as 20,000 at one hospital). Because about 20% of delivery records have missing SSNs, the impact of excluding these cases was explored through a variety of special analyses, described in a previous report.[3]

3. Delete duplicate or problematic records and re-sequence record sets

The files created in Step 2 above were joined and sorted by SSN, admission date, discharge date, date of birth, patient sex, and OSHPD facility number. The purpose of sorting by these variables was to identify any duplicate records that may have been pulled and to establish the correct sequence of linked records. After dropping duplicate records, reconciling discrepancies, and re-sequencing sets, the resulting file was divided into two new files: one containing SSNs with only one record (for which linkage was unnecessary) and another containing SSNs with multiple records. The latter file was used to identify and reconcile six anomalous types of delivery records (Table A.4):

[3] *Report of the California Hospital Outcomes Project. Maternal Outcomes Following Delivery: Risk-Adjusted Methodology and Preliminary Findings.* Sacramento, CA: Office of Statewide Health Planning and Development, September 1996.

a. **Cases that appeared to have two or more deliveries within six months (1-182 days).**

Six months is the shortest possible interval between two valid deliveries (except for multiple gestations with premature delivery of one infant), because women require at least 3-4 weeks after a delivery to resume ovulation. By definition, a delivery must involve a living or dead fetus that has a birth weight of at least 500 grams, or an estimated gestational age of at least 22 weeks. The expulsion of a smaller, younger fetus is defined as an abortion. Abortions were excluded from this study (see exclusion criterion #4). Therefore, linked records were used to exclude all patients who appeared to have two or more deliveries within 6 months (182 days).

However, miscoding of an abortion as a delivery is not the only possible explanation for two reported deliveries within 6 months. Some cases may have represented different women whose deliveries were incorrectly linked. Unfortunately, no personal identifiers other than the encrypted SSN and date of birth were available to validate the linkage of multiple deliveries. It was therefore assumed that all cases with two or more deliveries within 6 months were linked properly.

Another possible explanation for having two reported deliveries within 6 months is that one or both records was (were) misreported as "delivered" instead of "antepartum" or "postpartum." Note that the fifth digit of the obstetric diagnosis code indicates the episode of care: 0 represents "unspecified," 1 and 2 represent "delivered," 3 represents "antepartum," and 4 represents "postpartum." The fifth digits of 1 and 2 are intended to be used **only for patients who delivered during that hospital stay.** Two criteria were used to identify antepartum or postpartum hospitalizations mislabeled as deliveries, so that these records could be reclassified rather than excluded. First, all records **without** delivery procedure codes (based on the same list used to date deliveries above) and **without** diagnosis codes for the outcome of delivery (V27.x, 650) were identified. If the same patient had a record with **either** a delivery procedure code **or** a diagnosis code for the outcome of delivery, within 6 months before or after the record lacking such codes, the latter record was reclassified as an antepartum or postpartum hospitalization, as appropriate. Note that the list of delivery procedure codes excluded procedures that could have been performed during labor (e.g., fetal monitoring, induction of labor) or after delivery (e.g., repair of obstetric laceration, removal of retained placenta). Second, records with illogical fifth digit combinations (e.g., 1 or 2 with 3 or 4) were identified.[4] If another record without an illogical fifth digit combination was found for the same patient within 6 months, that record was assumed to represent the actual delivery and the illogically coded record was reclassified as an antepartum or postpartum hospitalization, as appropriate.

b. **Cases that appeared to have two deliveries within 6-8 months (183-224 days).**

Paired records of women who appeared to have two deliveries within six to eight months were then identified. Whereas it is physiologically impossible to have two deliveries from separate pregnancies (as defined in ICD-9-CM) within 181 days, multiple deliveries within 182-223 days are unusual but not impossible. These pairs were evaluated using the same algorithm described above, to determine whether one record was more likely to represent a prior admission or readmission rather than a delivery. For the remaining patients with two reported deliveries within 182-223 days, both records were retained in the analysis as delivery records.

c. **Delivery records sharing the same admission date.**

Some paired delivery records shared the same admission date. These pairs were inspected individually and manually classified as same-day transfers from one hospital to another, improperly linked records belonging to different patients, or duplicate records. Paired records from

[4] Coding guidelines state that no record should have obstetric diagnoses with a fifth digit of 1 or 2 **and** diagnoses with a fifth digit of 3 or 4, but this combination was seen in 0.3% of vaginal delivery records.

different hospitals were assumed to represent same-day transfers if either record had admission source or discharge disposition codes suggesting a transfer (but were otherwise excluded). Paired records from the same hospital were presumed to represent duplicates if they had any shared ICD-9-CM diagnosis or procedure codes in addition to the other patient identifiers used for matching. For each of these pairs, the record listing more procedure codes was selected as the index delivery record and the other was discarded. If the two records shared the same number of procedure codes, then the record showing a longer hospital stay was selected as the index delivery record. If they shared the same number of procedure codes and the same discharge date, then the record with higher total charges was selected as the index delivery record. Finally, paired records from the same hospital with the same admission date but without any shared ICD-9-CM diagnosis or procedure codes were excluded, because they were presumed to represent different patients.

d. **Records with admission dates 1-7 days apart and identical diagnoses and procedures.**

Some paired delivery records with identical diagnoses and procedures had admission dates one to seven days apart. These records were checked for differences in length of stay and total charges. If the length of stay differed, the record showing a longer stay was selected as the index delivery record. If the length of stay was the same, then the record with higher total charges was selected as the index delivery record. If both variables were identical, then both records for that SSN were excluded because the correct record, and the correct delivery date, could not be ascertained.

e. **Overlapping admission and discharge dates.**

Some paired records had overlapping hospital discharge and admission dates but did not fall into one of the above categories. That is, the admission date for the second record was earlier than the discharge date for the first record, and one or both records was a non-delivery. If the ICD-9-CM diagnosis and procedure codes were completely inconsistent, the records were presumed to belong to different patients and were excluded. There were a few pairs of nested hospitalizations, where the dates of an obstetric hospitalization were contained within the dates of a psychiatric hospitalization. These paired records were retained, and the psychiatric hospitalization was designated as antepartum. The remaining pairs with overlapping discharge and admission dates were excluded because the correct admission and discharge dates could not be determined, and it was therefore impossible to choose a single, accurate record from these pairs.

f. **Records with a principal or secondary diagnosis of hydatidiform mole (630), other abnormal product of conception (631), ectopic pregnancy (633.x), or other pregnancy with abortive outcome (634.xx-637.xx, 639.x) except failed attempted abortion, on any linked admission within 182 days prior to an otherwise eligible delivery, unless the same record also has a diagnosis of multiple pregnancy with fetal loss and retention (651.3x-651.6x).**

Cases with a diagnosis of molar, other abnormal, or ectopic pregnancy within 182 days prior to delivery were excluded for the same reason that cases with such a diagnosis on the delivery record were excluded. Cases with a prior diagnosis of abortion within 182 days prior to a delivery were excluded because of uncertainty about whether that subsequent delivery was eligible for study. The four possible explanations for this scenario include: (1) the "delivery" record was actually another abortion or an antepartum admission related to a later delivery; (2) the abortion and the subsequent delivery involved different women; (3) the "abortion" record was actually an antepartum admission; (4) the pregnancy was a multiple gestation with early loss of one fetus. Cases that fit the fourth explanation were retained, while all other cases with a diagnosis of abortion within 182 days prior to delivery were excluded. Note that the list of disqualifying

diagnoses does not include missed abortion (632) or failed attempted abortion (638.x), because these conditions are consistent with retention and subsequent delivery of a dead fetus.

Table A.4: Cases excluded after linkage of hospitalizations

Reason for Exclusion	number	%
Appeared to have two or more deliveries within 6 months, or within 6-8 months	366*	0.029*
Multiple records sharing same admit date (presumed to represent different patients)		
Multiple records with admit dates 1-7 days apart and identical diagnoses and procedures (presumed to represent duplicate records)		
Multiple records with overlapping admit and discharge dates	17	0.001
Principal or secondary diagnosis of hydatidiform mole (630), other abnormal product of conception (631), ectopic pregnancy (633.x), or other pregnancy with abortive outcome (634.xx-637.xx, 639.x) on any linked admission within 182 days prior to delivery, unless the same record also has a diagnosis of multiple pregnancy with fetal loss and retention (651.3x-651.6x	31	0.002
Transfers or other linked records within the peri-admission period that were not delivery admissions, readmissions, or antepartum admissions	1074	0.085
Total		

* Several exclusions were implemented in a single programming step, as the same record may have satisfied multiple criteria.

4. Order records in the period around the admission

The multiple record file created in step 3 included all records associated with a given SSN, including some admissions that were irrelevant to the study. The goals of step 4 were to identify the peri-admission period, consisting of an index delivery admission and the records around it, and to delete irrelevant records. The first step in establishing the peri-admission period was to identify index delivery records based on the inclusion and exclusion criteria described above. The next step was to identify postpartum records of potential interest by classifying all hospital admissions that occurred within six weeks after an index delivery as either transfers or readmissions (in the manner described on the next page). Some patients experienced multiple readmissions during the peri-admission period. Finally, all records that preceded an index record within the study frame were classified as prior (antepartum) admissions. Any record not flagged as an index delivery admission, readmission, or antepartum admission was then discarded. The multiple record file was ordered and combined with the single-admission file from Step 3 to create the final peri-admission file. Related records (e.g., prior, index, and postpartum admissions) were grouped into distinct peri-admission periods, as appropriate. The peri-admission file contained one or more peri-admission periods, each composed of one or more records for each SSN.

5. Create the linked single-record analysis file

Finally, the peri-admission file was reorganized into a linked analysis file containing one record for each peri-admission period (recognizing that a woman with multiple deliveries during the study period could have had multiple peri-admission periods). Diagnoses and procedures from antepartum and postpartum hospitalizations were attached to the appropriate peri-admission record. Demographic factors such as ethnicity, date of birth, and source of payment were occasionally documented differently across records, so only the values on the index delivery record were retained.

Linking Vital Statistics Files

Delivery records from OSHPD's Patient Discharge Data Set were linked with birth certificate records from the California Department of Public Health's vital statistics data system to build a more complete data set for analyses of risk-adjusted outcomes. For example, several key risk factors for perineal lacerations, such as birth weight and parity, cannot be obtained from the Patient Discharge Data Set alone. Several important exclusions could also be implemented only with data obtained from linked birth certificates.

The linkage between OSHPD's Patient Discharge Data Set and the CDPH's vital statistics birth file was performed by Health Information Solutions using a probabilistic method described in detail at: http://www.health-info-solutions.com/links.html. Probabilistic linkage provides the best possible match between records given the structure of the data. However, it is not a precise science, in that linkage errors do occur. Some of the matches produced may be false positives (not truly a match of records from the same person), while some records that should have matched may not have done so (false negatives). To minimize the number of false positive linkages, only linkages with maternal hospital discharge abstracts were used in this report. That is, linkages with infant hospital discharge abstracts were not used because these linkages rely more heavily on a technique labeled randomized matching, in which ties are resolved by randomly selecting one of multiple possible matches.

The probabilistic linkage procedure used the following variables from each maternal delivery record in the Patient Discharge Data Set: payer source; estimated date, month, and year of birth; delivery mode (cesarean versus vaginal); fetal death; ethnicity; hospital ID number; admission date; mother's date, month, and year of birth; maternal diagnosis-related group (DRG); hospital zip code; race; multiple birth; and zip code of residence.

The probabilistic linkage procedure used the following variables from each birth certificate in the vital statistics data set: birth weight; county of birth; delivery mode (cesarean versus vaginal); death indicator; date and month of infant birth; Hispanic origin; hospital ID number; mother's date, month, and year of birth; payer source; race; sex of child; multiple birth indicator; and zip code of residence.

Based on this linkage, three additional exclusion criteria were implemented to focus subsequent analyses on the cases of greatest interest (see Table A.5). Fetal deaths or stillbirths were excluded because nearly all such cases are now identified before delivery, and therefore special measures are taken to deliver the dead fetus in a way that minimizes risk to the mother (without regard to risk to the fetus). In other words, the delivery of stillborn infants involves a different set of outcomes of interest, and relevant risk factors, than the delivery of living infants. Birth weight was a very important risk factor for perineal lacerations, so matched records with missing or implausible birth weights (e.g., less than 250 grams or more than 6000 grams) were also excluded. Imputation is sometimes used to deal with implausible values of crucial predictor variables, such as birth weight, but this option was rejected because of the very small number of cases with missing or implausible birth weights. Finally, the duration of the interval between the current delivery and the last prior delivery was another important predictor, so a few cases with implausible intervals were excluded. Exactly 860,594 cases remained after these exclusions.

Table A.5: Cases excluded after linkage with vital statistics birth file

Reason for exclusion	Number of cases excluded	% of cases
Still births (fetal deaths)	7408	0.85
Birth weight <250 or >6000 grams	140	0.02
Months from last live birth <2 months	6	<0.01
Total exclusion after linkage	7554	0.87
Total cases in analysis cohort	860594	99.13

Selection and Measurement of Outcomes

Different outcomes are appropriate for different conditions. In selecting the specific outcomes for this analysis a variety of statistical and clinical issues were considered by the research team, with input from the Technical Advisory Committee and a special Clinical Expert Panel. This panel reviewed several previously identified sets of obstetric hospital performance measures, including those endorsed by the California Institute for Health System Performance, HealthGrades, the Joint Commission, the US Agency for Healthcare Research and Quality, the Leapfrog Group, the Maternal Quality of Care Working Group sponsored by the California Perinatal Quality of Care Collaborative, the National Committee for Quality Assurance, the US Public Health Service through Healthy People 2010, and other state health agencies.

Ultimately, two adverse outcomes were selected for analysis and reporting: perineal lacerations and postpartum maternal readmissions. OSHPD is also reporting primary and repeat risk-adjusted cesarean delivery rates, as these rates can be estimated using the same data and may be informative to interested consumers, although they are not specifically labeled as quality indicators.

Perineal Lacerations

Perineal lacerations occur during delivery and are classified by degree of tissue injury. First degree lacerations involve injury to the perineal skin and the epithelial lining of the vagina, but the underlying muscles remain intact. Second degree lacerations extend into the fascia and musculature of the perineal body, which includes the transverse perineal muscles and the pubococcygeus and bulbocavernosus muscles. Third degree lacerations additionally involve some or all of the fibers of the external or internal anal sphincter. Finally, fourth degree lacerations additionally involve the mucosal lining of the anus.

Although any type of perineal laceration during delivery is undesirable, third and fourth degree lacerations are particularly important because of their long-term consequences. Table A.6 presents the results of a comprehensive review of the published medical literature related to the long-term consequences of perineal lacerations after vaginal delivery. This review was performed using the MEDLINE bibliographic database from 1985 through 2002, with the assistance of a professional medical librarian. References were also identified through discussions with Clinical Expert Panel members and review of reference lists in relevant books and literature syntheses. Studies from developing countries (e.g., Africa and Central and South America) and studies limited to atypical populations (e.g., patients who had unusual procedures or risk factors) were not abstracted.

These studies generally found that third and fourth degree lacerations are associated with a markedly increased risk of long-term problems among affected women, including wound

breakdown, incontinence of stool, and involuntary release of flatus, which occasionally require later reoperation. Examination of these women using ultrasound and manometry (a device that records anal sphincter pressure) has shown that they often have reduced anal squeeze pressure and subtle defects in the sphincter, despite careful repair efforts immediately after delivery. Less commonly, women may experience painful intercourse or dyspareunia after repair of a perineal laceration. One study (listed as #8) found that episiotomy-associated lacerations are associated with an even greater risk of fecal and flatus incontinence than spontaneous lacerations of similar depth. More recent studies have generally confirmed these findings, but are not described here because a detailed literature review was not repeated after the decision was made to report perineal lacerations as an adverse outcome.

Over the past decade, several organizations have endorsed the use of third and fourth degree perineal lacerations as a quality measure. These organizations include the Joint Commission, the Agency for Healthcare Research and Quality, and the National Quality Forum (NQF). The NQF's endorsement at the end of 2002 was especially important, because the NQF (www.qualityforum.org) is a Congressionally chartered organization that brings together all stakeholders "to improve the quality of American healthcare by setting national priorities and goals for performance improvement, endorsing national consensus standards for measuring and publicly reporting on performance, and promoting the attainment of national goals through education and outreach programs." It applies a rigorous review process to evaluate candidate indicators based on specified criteria, with input from all key stakeholders.

Table A.6: Long term complications of 3rd and 4th degree lacerations after vaginal delivery: Summary of the literature

	Study	Study design and location	Findings
1	Kammerer-Doak, Wesol et al. 1999	15 women with anal sphincter laceration, after 6 weeks and 4 months. Albuquerque, NM.	Subjects with lacerations had more separated sphincters and increased anal resting and squeeze tone than control subjects. According to ultrasonographic evaluation, the anal sphincters were more commonly disrupted in the laceration group. Subjective rating of fecal incontinence was significantly greater in the laceration group than in the control group. At the 4-month visit, fecal incontinence was resolved in 36% of subjects; however continued anorectal dysfunction was reported by 43% of subjects in the laceration group vs. only 7% of the control group (P=0.08).
2	Fitzpatrick, Fynes et al. 2000	154 women after primary repair following 3rd degree tear. Ireland.	Symptoms of altered fecal continence 3 months postpartum were recorded in 82/154 (53%) women. Of these women, 75 (91%) were incontinent to flatus only, 3 (4%) incontinent to both flatus and liquid stool and four (5%) women complained of episodic incontinence to solid stool. There was no significant manometric difference between primiparous and multiparous patients 3 months following repair. There was also no difference in manometry with respect to the method of sphincter repair or the presence of symptoms. A persistent defect in 0-1 quadrants of the anal circumference was found in 80 (52%) women, while 51 (33%) women had a persistent defect involving more than one quadrant of the anal circumference. The authors conclude that the outcome of anal sphincter injury was not influenced by parity or mode of repair. Despite good symptomatic outcomes, ultrasound evidence of significant anal sphincter injury was found in one-third of patients.
3	Zetterstrom, Lopez et al. 1999	OB procedures, maternal and fetal data registered in 845 consecutive vaginal deliveries. Sweden.	Of 46 women with clinically detected sphincter injury, 4% had fourth degree tears, 15% had third degree tears involving the complete sphincter, and 80% had tears involving just parts of the sphincter. Before pregnancy, 2% had symptoms of fecal incontinence and an additional 13% had gas incontinence only. At 5 months after primary sphincter repair, 4% had symptoms of fecal incontinence and an additional 50% had gas incontinence only. At 9 months after primary repair, 2% had symptoms of fecal incontinence and an additional 39% had gas incontinence only. Of women having symptoms before pregnancy, three had undergone one previous vaginal delivery, one had undergone two previous vaginal deliveries and three were nulliparous.
4	Sultan, Kamm et al. 1994	8603 women who delivered vaginally over a 31 month period. 34 women who sustained a third degree tear and 88 matched controls. UK.	Anal incontinence or fecal urgency was present in 16 women with tears and 11 controls (P=0.00001). Sonographic sphincter defects were identified in 29 (85%) with tears and 29 (33%) controls (P=0.00001). Every symptomatic patient had persistent combined internal and external sphincter defects, which were associated with significantly lower anal pressure. Pudendal nerve terminal motor latency measurements were not significantly different between women with 3rd degree tears and matched controls. The authors conclude that primary repair is inadequate in most women who sustain third degree tears. Most have residual sphincter defects and about half experience anal incontinence, which is caused by persistent mechanical nerve damage.
5	Venkatesh, Ramanujam et al. 1989	Anorectal complications following vaginal delivery in 20500 women. 1040 NVDs resulted in episiotomy with 3rd or 4th degree extension or a 4th degree perineal tear. USA.	Of 1040 NVDs resulting in 3rd or 4th degree extension of an episiotomy or 4th degree lacerations, 101 patients (10%) experienced wound disruption after primary repair. Sixty –seven patients (66%) experienced wound disruption that required surgical correction. There was incontinence of flatus and feces in 41 (40.5%) of women. Anorectal complications were anal ulcer, anorectal abscess, sphincter disruption, and rectovaginal fistula.
6	Zetterstrom, Mellgren et al. 1999	38 primiparous patients evaluated with endoanal ultrasonography, anal manometry, and pudendal nerve terminal motor latency during pregnancy and after delivery. Minnesota, USA.	Clinical sphincter tears requiring primary repair occurred in 15% of the patients. After delivery, endoanal ultrasonography revealed disruptions in the external anal sphincter in seven patients. One patient had slight scarring in the external sphincter. Of the seven patients with pathologic findings at endoanal ultrasonography, the left pudendal nerve latency increased after delivery (P<0.05), and pressures recorded by manometry were reduced. Three of these seven patients had a third degree or fourth degree laceration during delivery.
7	Eason, Labrecque et al. 2000	949 pregnant women. Quebec, Canada.	Three months after delivery, 29 women (3.1%) reported incontinence of stool, and 242 (25.5%) had involuntary escape of flatus. Incontinence of stool was more frequent among women who delivered vaginally and had third or fourth degree perineal tears than among those who did not have tears. Occurrence of an anal sphincter tear (adjusted RR 2.09, CI=1.4-3.1) was an independent risk factor for incontinence of flatus or stool or both.
8	Signorello, Harlow et al. 2000	Retrospective cohort study with 6 month of follow up of 626 women. USA.	Comparing women with episiotomy to women with spontaneous 3rd or 4th degree lacerations, episiotomy tripled the risk of fecal incontinence at three months (95% CI = 1.3-7.9) and six months (95% CI =0.7-11.2) postpartum, and doubled the risk of flatus incontinence at three months (95% CI = 1.3-3.4) and six months (95% CI = 1.2-3.7) postpartum.

	Study	Study design and location	Findings
9	Williams, Bartram et al. 2001	To determine the incidence and functional consequences of external trauma to anal sphincter in 55 nulliparous women. UK.	13 of 55 nulliparous women had postpartum trauma evidenced by ultrasound. External sphincter trauma was associated with a significant decrease in squeeze pressure (P=.035) and an increase in incontinence score (P=.02), compared with women who did not have trauma.
10	Gjessing, Backe et al. 1998	38 women examined one to five years after delivery with a history of 3rd degree tear in NVD. Norway.	57% of women with a history of 3rd degree tear had symptoms; most of them (43%) in the form of flatus incontinence. The rest (14%) were incontinent of either liquid or solid stools. Four of these women were re-operated. Seventeen percent of the women suffered from anal incontinence during sexual intercourse. Only seven women had been in contact with a doctor regarding these problems.
11	Sorensen, Tetzschner et al. 1993	38 women with rupture of anal sphincter occurring during delivery followed for 3-12 months. Denmark.	14 of 38 patients presented with continence disturbance: nine to solid or liquid feces and five to flatus. Incontinence was present in 9 women 3 months after delivery. Anal manometry and electromyography were performed in patients at 3-5 days and at 3, 6, and 12 months.
12	Nielsen, Hauge et al. 1992	24 women with primary suture of tear of the anal sphincter examined with anal endosonography 3-18 months after delivery. Denmark.	Endosonography was normal in ten patients, of whom one was incontinent. Endosonographic examination showed a defect in the external anal sphincter in 13 patients; six of these were incontinent, of whom two had normal findings on palpation. An isolated internal sphincter defect was found in one continent patient.
13	Sultan, Kamm et al. 1993	202 consecutive women six weeks before delivery, 150 of them six weeks after delivery, and 32 with abnormal findings six months after delivery. UK.	10 of the 79 primiparous women and 11 of the 48 multiparous women who delivered vaginally had anal incontinence or fecal urgency when studied six weeks after delivery. Twenty-eight of the 79 primiparous women had a sphincter defect on endosonography at six weeks; the effect persisted in all 22 women studied at six months. Of the 48 multiparous women, 19 had a sphincter defect before delivery and 21 afterward. Internal sphincter defects were associated with a significantly lower mean resting anal pressure six weeks postpartum, and external sphincter defects were associated with a significantly lower squeeze pressure. There were a strong association between sphincter defects and the development of bowel symptoms.
14	Mellerup Sorensen, Bondesen et al. 1988	25 women with complete perineal rupture were compared with 25 controls. Denmark.	42% of the women in the rupture group reported anal incontinence, compared with none in the control group (P<0.01). Most of these women reported stress-provoked incontinence of flatus and loose stools. Measurement of the anal pressure profile showed markedly reduced sphincter pressure, with maximum squeeze in the rupture group, but no differences were found regarding maximum anal pressure at rest. Sphincter length was reduced both at rest and with maximal squeeze in the rupture group. It is concluded that complete perineal rupture is a condition with possible long-term consequences such as reduced sphincter strength and partial anal incontinence.
15	Walsh, Mooney et al. 1996	16583 vaginal deliveries were prospectively assessed over a 5.5 year period. UK.	Of the 81 patients with tears who were reviewed, 30 had an abnormal anorectal examination. Six patients (7%) were incontinent of feces, and another ten (12%) were incontinent of flatus only. The overall incidence of fecal incontinence was 0.04%.
16	Haadem, Dahlstrom et al. 1987	8542 women delivered vaginally, of whom 63 (0.7%) experienced rupture of anal sphincter. Sweden.	Questionnaires were sent to 63 women with anal sphincter rupture that occurred during vaginal delivery two to seven years earlier. Half of them had significant trouble, such as incontinence for gas, dyspareunia, and pain. In 14 women and 10 controls, pressure profilometry was performed and found significantly reduced strength in the external anal sphincter. When anal sphincter rupture extended through the rectal mucosa, the internal sphincter strength was also reduced.
17	Bek and Laurberg 1992	152 women with complete obstetric tear of the anal sphincter. Denmark.	56 respondents had experienced a subsequent vaginal delivery; 23 of these women had had transient anorectal incontinence after the complete tear and four (7%) had permanent anorectal incontinence. In the 23 women with transient anorectal incontinence directly after the complete tear, 9 (39%) developed anorectal incontinence after the next delivery, and this was permanent in four. In the 29 women without anorectal incontinence after complete tear, two had transient incontinence of flatus but for less than 14 days after the next delivery.
18	Persson, Wolner-Hanssen et al. 2000	To evaluate obstetric and maternal RFs for stress urinary incontinence, three national, Swedish, population based registrars were linked. Sweden.	No association was found between surgery for stress incontinence and large perineal tears.

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Perineal lacerations were felt to be particularly useful quality measures because of evidence that it is possible to reduce their incidence in developed countries. As described in a recent review of the literature:[5] "The incidence of severe perineal trauma can be decreased by minimizing the use of episiotomy and operative vaginal delivery. A Cochrane review demonstrated that liberal use of episiotomy does not reduce the incidence of anal sphincter lacerations and is associated with increased perineal trauma. [Evidence level A, systematic review of RCTs] A meta-analysis of eight randomized trials of vacuum extraction versus forceps delivery demonstrated that one sphincter tear would be prevented for every 18 women delivered with vacuum rather than forceps. [Evidence level B, systematic review of lower quality RCTs]."

A review of this literature, based on the same methods described above, is shown in Table A.7. Note that the factors highlighted in gray are potentially under the control of the physicians and nurses treating the patient, and thus are not used in risk-adjustment models. They are included here simply to demonstrate opportunities for improvement if these practices are modified. The pre-delivery risk factors identified from this review include primiparity (first delivery), macrosomia or high birth weight, shoulder dystocia, breech presentation, prolonged second stage of labor, history of perineal trauma during a prior delivery, and newborn head circumference. Maternal age and race have been significant predictors in some prior analyses, but not all. The Joint Commission's empirically derived risk-adjustment model for this Core Measure (PR-3) includes several of these factors, as captured in ICD-9-CM hospital discharge abstracts, plus a few others: maternal age, abnormal presentation, multiple gestation, "cephalopelvic disproportion," large fetus (yes/no), precipitate labor, episiotomy, breech delivery, shoulder dystocia, vacuum extraction, and forceps delivery. However, the Joint Commission's model does not include parity and birth weight, because these variables cannot be captured from maternal hospital discharge abstracts alone. The use of information from both maternal hospital discharge abstracts and linked infant birth certificates for risk-adjustment is a crucial advantage of OSHPD's method for analyzing risk-adjusted perineal laceration rates.

[5] Leeman L, Spearman M, Rogers R. Repair of obstetric perineal lacerations. Am Fam Physician 2003; 68:1585-90.

Table A.7: Predictive variables for 3rd or 4th degree vaginal laceration in normal delivery: Summary of the literature

Number	Source	Data Source	Inclusion / Exclusion criteria	primiparity	Macrosomia	Race	Episiotomy	Vacuum	forceps	Use of instruments	Fundal pressure	Maternal position	Epidural anesthesia	Oxy. Augmentation	Operator	Maternal/neonatal index	Shoulder dystocia	Neonatal presentation	Gestational age	Length of 2nd stage of labor	Hx of perineal trauma in 1st	Newborn head circumference	Maternal age	Others
1	Handa, Danielsen et al. 2001*	California OSHPD Database: BC and maternal & newborn DS. USA.	Excluded preterm birth, stillbirth, breech, multiple gestation.	+	2.17	1.63 2.50	0.81 1.12	2.30	1.45	-	-	-	-	-			2.67	-	-	-	-	-	-	-
2	Jones 2000*	John Radcliff hospital, computerized records and case notes. UK	-	-	1.56	-	2.14	-	4.15	-	-	-	-	-			-	10.9 6.82	-	-	-	-	-	-
3	Zetterstrom, Lopez et al. 1999*	Karolinska Institute, Sweden.	Excluded women not able to speak or read Swedish.	9.8	1.3	-	5.5	-	-	6.5	4.6	2.2, 4.6 0.4 0.3	2.3	4.1			-	-	2.5	2.6	-	-	-	-
4	Martin, Labrecque et al. 2001*	Obstetric computerized database, Saint-Sacrament Hospital, Canada.	Included nulliparous and primiparous women who gave birth vaginally to a single living neonate and did not have an episiotomy.	-	2.3	-	3.3	1.3	1.5	-	-	-	1.1	-			1.3	1.9	1.6 1.9 1.9	-	3.3	1.5 1.7 1.9 2.3		-
5	Angioli, Gomez-Marin et al. 2000*	Jackson memorial hospital, University of Miami, USA.	Excluded malpresentation, multiple gestation, history of previous C/S, shoulder dystocia, birth weight<500g.	4.22	2.5 3.1 4.0 5.4	-	2.29 5.24	2.66	7.07	-	-	-	-	-			-	-	-	-	-	-	1.53 1.7 1.9	-
6	Shihadeh and Nawafleh 2001	Perinatal records and files of Prince Hashim Military Hospital, Jordan.	Singleton deliveries were included.	+	+	-	+	-	-	+	-	-	-	-			-	-	-	-	-	-	-	-
7	Borgatta, Piening et al. 1989*	Albert Einstein college of medicine, New York, USA.	Included singleton vertex deliveries. Excluded instrumented deliveries.	-	-	-	22.4 14.0	-	-	-	-	-	-	-			-	-	-	-	-	-	-	-

Number	Source	Data Source	Inclusion / Exclusion criteria	primiparity	Macrosomia	Race	Episiotomy	Vacuum	forceps	Use of instruments	Fundal pressure	Maternal position	Epidural anesthesia	Oxy. Augmentation	Operator	Maternal/neonatal index	Shoulder dystocia	Neonatal presentation	Gestational age	Length of 2nd stage of labor	Hx of perineal trauma in 1st	Newborn head circumference	Maternal age	Others
8	Jander and Lyrenas 2001	Dept of women's and health, in a referral hospital, Sweden.	-	7.55	3.98	-	3.44 0.71	3.49 2.71	-	-	-	6.47	0.56	2.00			-	-	-	-	2.26	-	4.79	2.07
9	Legino, Woods et al. 1988	University of Nebraska, Omaha, USA.	Excluded breech presentation, multifetal gestation, mediolateral episiotomy were excluded.	+	NS	-	-	-	+	-	-	-	+	+			-	-	+	-	-	-	+	-
10	Wilcox, Strobino et al. 1989 *	Data abstracted from medical records from two institutions in Philadelphia, USA.	Women with C/S, cervical laceration, and combination laceration were excluded.	2.08	-	NS	-	-	1.9	-	-	-	-	-		-	-	1.71	-	1.63	-	1.18	-	-
11	Poen, Felt-Bersma et al. 1997*	OB ward log books and computerized database. Netherlands.	Vaginal delivery at gestational age at least 36 weeks were included.	NS	2.05	-	NS	1.29	3.90	-	-	-	8	6.97			-	1.0 3.53 9.8	NS	2.2	-	-	NS	-
12	Bodner-Adler, Bodner et al. 2001*	Dept of obstetric and gynecology of university of Vienna Medical school, Austria.	All women with uncomplicated pregnancy as well as uncomplicated 1st and 2nd stages of labor, gestational age>37 weeks and cephalic presentation were included. Multiple gestations, C/S, and shoulder dystocia deliveries were excluded.	0.4	-	-	0.17 10.1 NS	-	3.4	-	-	-	NS	0.4		-	-	-	-	2.2	-	1.4	NS	-
13	Howard, Davies et al. 2000*	Review of University of Michigan Hospital patent charts, USA	Women with 1st vaginal delivery (plus VBAC) with a black or white identification.	-	0.69	2.1	-	0.55	0.32	-	-	-	NS	NS		-	-	-	NS	-	-	-	0.94	-

Number	Source	Data Source	Inclusion / Exclusion criteria	primiparity	Macrosomia	Race	Episiotomy	Vacuum	forceps	Use of instruments	Fundal pressure	Maternal position	Epidural anesthesia	Oxy. Augmentation	Operator	Maternal/neonatal index	Shoulder dystocia	Neonatal presentation	Gestational age	Length of 2nd stage of labor	Hx of perineal trauma in 1st	Newborn head circumference	Maternal age	Others
14	Robinson, Norwitz et al. 1999 *	Review of medical records	Non-diabetic nulliparas at or after 36 weeks with singleton pregnancies. Spontaneous and induced labors included.	-	2.5	0.5 1.5	-	-	-	-	-	-	1.4	NS		-	-	-	-	-	-	-	NS	-
15	Walsh, Mooney et al. 1996	A prospective study of 16583 NVDs, Illinois, USA	All vaginal deliveries in a 5.5-year period in a certain population.	+	+	-	+	-	+	-	-	-	-	-		-	-	-	-	-	-	-	NS	-
16	Riskin-Mashiah, O'Brian Smith et al. 2002*	Retrospective study of computerized perinatal database of 23244 vaginal deliveries. Texas, USA.	Singleton vaginal vertex deliveries.	6.4	2.35 0.52	1.75	6.91 2.33	1.81	4.48	-	-	-	1.27 5.63	1.17		-	2.04	-	-	-	-	-	-	--
17	Mellerup Sorensen, Bondesen et al. 1988 *	25 women with complete perineal rupture compared to matched controls. Denmark.	All cases with complete perineal rupture following vaginal delivery within 7 years.	-	-	-	-	+	-	-	-	-	-	+		NS	-	NS	-	-	-	-	-	-
18	Moller Bek and Laurberg 1992 *	Case control study of 152 cases of complete anal sphincter tear among 41200 deliveries. Denmark.	All normal vaginal delivery cases with complete anal sphincter tear.	2.7	BW 1.6	-	2.8	+	4.4	+	-	-	-	+		-	58.9	+	-	1.6	-	-	+	NS
19	Meyer, Mailloux et al. 1987 *	Study of 761 instrumental deliveries, Quebec, Canada.	Eligible subjects were women who required an instrumental delivery in a certain time period and place. All had a singleton, vertex pregnancy at 37 or more weeks of gestation.	-	-	-	-	-	-	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Number	Source	Data Source	Inclusion / Exclusion criteria	primiparity	Macrosomia	Race	Episiotomy	Vacuum	forceps	Use of instruments	Fundal pressure	Maternal position	Epidural anesthesia	Oxy. Augmentation	Operator	Maternal/neonatal index	Shoulder dystocia	Neonatal presentation	Gestational age	Length of 2nd stage of labor	Hx of perineal trauma in 1st	Newborn head circumference	Maternal age	Others
20	Combs, Robertson et al. 1990 *	Study of 2832 instrumental vaginal deliveries. California, USA.	Women who had forceps or vacuum delivery, vertex presentation, single gestation, gestational age > 35 weeks. "High forceps" and vacuums or forceps resulting in C/S were excluded.	3.56	NS	1.31	7.81	-	-	1.90	-	-	-	-	NS	-	-	1.6	NS	1.56	-	-	-	1.56 1.49
21	Payne, Carey et al. 1999	Computerized prenatal database of 1741 vaginal deliveries. Oklahoma, USA.	Women who were delivered vaginally, a singleton fetus at the hospital in the study on two consequences occasions in a 4-year period.	-	NS	-	17.4	6.5	5.0	-	-	-	-	-	-	-	-	-	-	-	3.4	-	-	-
22	Sultan, Kamm et al. 1994	Retrospective analysis of 50 women with 3rd degree tear. UK	All women who delivered vaginally over a 31 month period and sustained a 3rd degree tear.	+	+	-	-	NS	+	-	-	-	NS	NS	-	-	NS	+ Occi Post .	-	-	-	-	-	-
23	Otigbah, Dhanjal et al. 2000 *	A retrospective study over a five-year period of 301 water birth. UK.	Women with water births were compared with age, parity matched low risk women having conventional vaginal deliveries.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
24	Klein, Janssen et al. 1997*	459 nulliparous women. Canada.	Women who were able to give informed consent in English or French, 17 to 40 yr. old, para 0,1, or 2, carried a single fetus, 30 to 34 weeks of gestational age, with no risk.	-	-	-	-	-	-	-	-	-	-	-	-	NS	-	-	-	-	-	-	NS	-

Number	Source	Data Source	Inclusion / Exclusion criteria	primiparity	Macrosomia	Race	Episiotomy	Vacuum	forceps	Use of instruments	Fundal pressure	Maternal position	Epidural anesthesia	Oxy. Augmentation	Operator	Maternal/neonatal index	Shoulder dystocia	Neonatal presentation	Gestational age	Length of 2nd stage of labor	Hx of perineal trauma in 1st	Newborn head circumference	Maternal age	Others
25	Robinson, Norwitz et al. 1999 *	323 consecutive operative vaginal deliveries. Massachusetts, USA	Non-diabetic nulliparous women at >36 weeks gestation with e singleton, cephalic fetus.		+ /NS	+ /NS	-	6.8	15.8 11.0	-	-	-	-	+ /NS	NS	-	NS	NS	-	-	-	-	+ NS	-
26	Buekens, Lagasse et al. 1985 *	**21278 singleton deliveries.** Belgium.	In a 4 year period all singleton deliveries in 10 hospitals	-	-	-	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	Anthony, Buitendijk et al. 1994 *	Data of 43309 NVDs were delivered from Dutch National Obstetric Database. Netherlands.	Spontaneous, occipita anterior of live, singleton infants.	1.96	0.47 1.63	0.55 1.3	0.22 1.08	-	-	-	-	--	-	0.91	1.01 1.78	-	-	-	0.4	0.67 1.01	-	--	0.45 1.0	-
28	Labrecque, Baillargeon et al. 1997*	6522 women with NVD. Quebec, Canada.	Primiparous women who gave birth vaginally to a single live baby in cephalic position in a 8 year period of time.	-	3.15 1.79	-	4.58	1.68	3.99	-	-	-	1.5	-	1.06 1.27 0.94	-	1.92	-	2.37 2.07	-	-	1.68	1.69 1.92 1.63 1.50	-
29	Samuelsson, Ladfors et al. 2000 *	Studying 2883 patients' records of consecutive women delivered in a 2-year period of time. Sweden.	Women delivered vaginally.	2.38 6.51	2.37 3.27	-	2.34	4.06	-	-	-	-	2.23	2.07 2.57	-	-	-	1.88 Occi Post .	-	3.68 5.19 5.16	-	-	-	3.57 6.00 2.91 1.37 4.91 6.81
30	Green and Soohoo 1989*	2706 deliveries in San Francisco general hospital. California, USA.	Twins, breeches, and infants weighing <1500 as well as C/S were excluded from 4172 deliveries.	3.3	2.4	1.3 1.9 3.7 2.9	8.9	-	-	-	-	-	-	-	2.4	-	-	-	-	-	-	-	-	2.0

31	Peleg, Kennedy et al. 1999*	A retrospective study used a prenatal database and chart review of 17 years. 4015women were included. Iowa, USA.	4015 women who were nulliparous, gestational age greater than 36 wk, singleton, and vertex presentation who had a subsequent delivery.	-	+ NS	-	4.1 1.5	-	-	3.6 1.4	-	-	-	-	-	-	-	-	-	-	2.5	-	NS	-
32	Mayerhofer, Bodner-Adler et al. 2002*	A prospective, randomized multicenter study of 1161 NVDs. Austria.	To study the traditional hands-on vs. the innovative hands-poised method on the risk of perineal trauma during NVD.	0.79 0.94	-	-	4.3 6.1	-	-	-	-	0.62 0.7	-	NS	-	-	-	-	-	-	-	1.18	NS	1.01
33	Eason, Labrecque et al. 2002 *	The study of 949 pregnant women. Canada.	Women with or without a previous vaginal delivery.	-	1.4	-	9.6	7.4	12.3	-	-	-	-	-	-	-	-	-	-	-	-	-	NS	1.4 NS
34	Ural, Roshanfekr et al. 2000	Study of 11038 NVDs. New York, USA	Study 4th degree laceration	-	-	-	4.29	-	-	5.18	-	-	NS	NS	-	-	-	-	-	-	-	-	-	-

+: No specific odds ratio or risk ratio is reported in the article although authors mention there is a significant relation between the variable of interest and 3rd or 4th degree laceration.
-: The variable was not studied in the article.
NS: The variable was studied in the article and found not to be significant.

Asterisks are explained below:

	Study	Footnotes
1	Handa, Danielsen et al. 2001	Primiparity serves as reference: women with prior vaginal birth OR = 0.15 comparing to primiparous. Race: Indian women=2.5, Filipina=1.63 Episiotomy decreased the likelihood of 3rd=0.81, but increased 4th = 1.12
2	Jones 2000	Relative Risks Episiotomy poster-lateral RR = 2.14 when considering spontaneous cephalic vaginal deliveries. Occipitoposterior (OP) position considering all deliveries RR= 10.9, only spontaneous cephalic vaginal deliveries RR= 6.82
3	Zetterstrom, Lopez et al. 1999	OR of second stage of labor, duration of labor, oxytocin, epidural anesthesia, maternal position and use of instruments are from a univariate model. OR is for a midline episiotomy. Gestational age>294d Maternal position: sitting = 2.2, lithotomy = 4.6, kneeling = 0.4, upright = 0.3 Second stage labor >1hour (also tested duration of labor > 12 hours and obtained the same OR)
4	Martin, Labrecque et al. 2001	RR is reported. RR of a 3rd or 4th degree laceration in the second delivery with a history of episiotomy without in prior delivery= 3.3 Non-vertex presentation = 1.9 Gestational age weeks: 37-38=1.6, 39-40=1.9, >=41=1.9 Newborn head circumference: 33-33.9=1.5, 34-34.9=1.7, 35-35.9-1.9, >36=2.3.
5	Angioli, Gomez-Marin et al. 2000)	Episiotomy mediolateral=2.29, midline=5.24 Birth weight: 4000-4249=2.52, 4250-4499=3.18, 4500-4749=5.04 Maternal age: 31-35=1.53, 36-40=1.7, >41=1.9
7	Borgatta, Piening et al. 1989)	Deep perineal tears occurred in 0.9% of the women delivered of infants without the use of either Episiotomy or stirrups and in 27.9% of the women delivered of infants with both Episiotomy and stirrups. Women exposed to Episiotomy alone or stirrups alone had intermediate rates of laceration. Effect of episiotomy=22.45, effect of stirrups 14.06
8	Jander and Lyrenas 2001)	Maternal position: Delivery with squatting on a low chair Other: giving birth at 3-6 am (OR=2.07)
10	Wilcox, Strobino et al. 1989)	Non-vertex presentation=1.71 Infant head circumference>35cm = 1.18 Second stage labor > 90 min
11	Poen, Felt-Bersma et al. 1997	Mediolateral episiotomy = NS Occipito-anterior=1, occipito-posterior=3.53, median vertex=9.8 Second stage labor> 1hour ORs of forceps, parity, induced labor and epidural are calculated by multivariate analysis. Others are by univariate analysis. Maternal age, gestational age and parity are continuous data.
12	Bodner-Adler, Bodner et al. 2001	The study is for 3rd degree lacerations. Episiotomy: yes vs. no=0.17, midline vs. no = 10.1, mediolateral vs. no =NS Nulliparous: 2 vs. 1 = 0.4 2nd stage labor (min = log transformed = 2.2 Oxytocin no vs. yes = 1.8
13	Howard, Davies et al. 2000	Predictors of delivery with an intact perineum. The odd ratios indicate how likely an individual would deliver with an intact perineum given the presence of each listed variable. Black race = 2.1
14	Robinson, Norwitz et al. 1999	Race: Black = 0.5, other race=1.3

	Study	Footnotes
16	Riskin-Mashiah, O'Brian Smith et al. 2002	Episiotomy: midline=1.93, mediolateral=0.84 Analgesia: Pudendal = 5.63, epidural 1.27 Ethnicity: Asian=0.56
17	Mellerup Sorensen, Bondesen et al. 1988	Maternal/neonatal index = maternal (height weight)/ neonatal (height * weight)
18	Bek and Laurberg 1992)	Other: perineum rigidus = NS, neonatal asphyxia = NS Maternal age: mean in cases = 26.2 and in controls = 27.2, a significant difference Birth weight: mean in cases = 3641 g and in controls = 3496 g, a significant difference Presentation: occiput anterior = S, occiput posterior = S, face and brow presentation = S, twins = NS, Breech = NS ORs are adjusted
19	Meyer, Mailloux et al. 1987	Perineal tears (3^{rd} or 4^{th} degree) were 18.8% and 23.9% among vacuum extractor and low forceps groups, respectively. RR=0.78 NS
20	Combs, Robertson et al. 1990	Instruments: forceps vs. vacuum=1.90 Other: arrest of descent present vs. absent=1.56 Other: anesthesia local/pudendal vs. conduction = 1.49 Ethnic group = Asian vs. white/black/Hispanic = 1.31 Operator: faculty vs. resident = NS
23	Otigbah, Dhanjal et al. 2000	Water birth: Tears in water birth was 159 and in controls 115. Related p-value was <0.001
24	Klein, Janssen et al. 1997	Maternal weight before pregnancy: NS Weight gain during pregnancy: NS Maternal height: NS Kegal excursuses performed (ante partum): NS Exercise status: strenuous exercise performed >3 times/week : significant p-value=0.003 Book read: NS EMG perineometry (ante partum-10 sec holds): NS Marital status, education, employed, and partner employed: NS
25	Robinson, Norwitz et al. 1999	A multiple logistic regression was performed on data to examine the effects of method of operative vaginal delivery and Episiotomy while potential confounding factors were controlled for. In that model the associations with significant perineal trauma of maternal age, race, and use of oxytocin, and birth weight were not statistically significant.
26	Buekens, Lagasse et al. 1985	The data were analyzed in two steps. In the first step, the relation between Episiotomy and 3^{rd} degree tear was investigated in all deliveries. In the 2^{nd} step, the analysis was restricted to a sub-sample that included only the vertex presentations with spontaneous occiput anterior vaginal deliveries.
27	Anthony, Buitendijk et al. 1994	Episiotomy: mediolateral OR= 0.31, midline=1.36 NS Ethnic group: medit./Surinam = 0.55, Asian = 1.28 NS Gestational age: <37 week vs. >37 weeks = 0.28 Birth weight: <2500 gr = 0.47, >4000 = 1.63 Length of 2^{nd} stage: <16 min = 0.67, >90 min = 1.1 NS Operator: doctor = 1.19 NS, medical student = 1.78
28	Labrecque, Baillargeon et al. 1997	Birth weight: >4000 = 3.15, 3000 –3999 = 1.79 Baby's head circumference, cm: >35 = 1.68 Gestational age: >41 wk = 2.37, 37-40 wk = 2.07 >35 = 1.69, 30-34 = 1.92, 25-29 wk = 2.07, 20-24 wk = 1.5 operator: obstetricians-gynecologist = 1.06 NS

	Study	Footnotes
29	Samuelsson, Ladfors et al. 2000	ORs from univariate analyses of the association between intrapartum variables and sphincter tear. Parity: 1 previous delivery = 2.38 NS, nulliparity = 6.51 Infant weight: 3000-4000 = 2.37, >4000 = 3.27 Duration of 2nd stage of labor: 30-59 min = 3.68, 60-89 min = 5.19, >90 min = 5.16 Mediolateral Episiotomy = 2.34 Oxytocin during 1st stage = 2.07, oxytocin during 2nd stage = 2.57 Others: perineal oedema: moderate = 3.57, severe = 6.00, visualization of perineum during last phase of bear down: partial = 1.37, no visualization = 4.91, no manual perineal protection = 2.91, duration of bear down : 30-39 min = 6.81, 40-49 = 4.84, 50-59 = 7.25, >25 min = 4.74
30	Green and Soohoo 1989	Operator: physician vs. midwife = 2.4 Others: delivery room vs. labor bed = 2.0 Birth weight: LBW vs. normal = 0.5, macrosomia vs. normal = 2.4 Black vs. white = 1.3 NS, Hispanic vs. white = 1.9, Filipino vs. white = 3.7, Chinese vs. white = 2.9
31	Peleg, Kennedy et al. 1999	Birth weight in the 1st delivery was not significant between two groups with previous and without previous trauma.
32	Mayerhofer, Bodner-Adler et al. 2002	Parity: 2 vs. 1 / 2vs.2 = 0.79 (univariate OR) 0.58 (multivariate OR) Maternal position: sitting, squatting or all fours vs. supine = 0.625, lateral recumbent vs. supine = 0.74 NS
33	Eason, Labrecque et al. 2002	Others: maternal body index = 1.4, weight gain during pregnancy = NS Total labor duration was also tested and found NS

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Postpartum readmissions

The second outcome measure for childbirth patients was readmission for a postpartum complication within 6 weeks (42 days) after the date of delivery. This interval was chosen because it corresponds to the definition of the postpartum period in the *International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM)*. Although readmissions are infrequent, they have major implications related to both resource utilization and patients' quality of life. Only the most serious complications require a woman to be readmitted to a hospital.

It should be recognized that this quality indicator has not been endorsed by any major national organizations, such as the Joint Commission, the Hospital Quality Alliance, or the National Quality Forum. It was newly developed and validated by the UC Davis research team, under contract with OSHPD. Because of the promising results from OSHPD's Postpartum Maternal Outcomes Validation Study,[6] OSHPD decided to proceed with publication of a report using this indicator. In the last few years, there has been increasing interest in such readmission-based measures of hospital performance. In May 2008, for the first time, the NQF endorsed two readmission-based measures: Pacificare's "All-Cause Readmission Index" (30-day, risk-adjusted) and the Center for Medicare and Medicaid Services' "30-Day All-Cause Risk Standardized Readmission Rate Following Heart Failure Hospitalization." OSHPD's measure of postpartum maternal readmissions is conceptually similar to these two NQF-endorsed measures.

Using encrypted social security numbers and dates of birth, as previously described, postpartum readmissions within 6 weeks were linked with the preceding delivery and attributed to the hospital where that delivery was performed (regardless where the patient was readmitted). If a woman had a missing or invalid social security number (SSN), her readmissions would not have been detected in this study. For this reason, patients with missing or invalid SSNs were excluded from the readmissions analysis, while they were included in the analysis of perineal lacerations.[7] Several types of readmissions were not counted against a hospital:

1. **Readmissions to non-acute care facilities.**

Of a previously evaluated sample of 148 readmissions to non-acute care facilities, 141 involved psychiatric hospitals, 2 involved skilled nursing facilities, 3 involved rehabilitation hospitals, and 2 involved inpatient alcohol or drug treatment programs. These readmissions to non-acute care facilities (including dispositions of "other care within this hospital" [03], "skilled nursing/ intermediate care within this hospital" [04], "other care to another hospital" [06], or "skilled nursing/intermediate care to another hospital" [07]) were not counted because they are unlikely to represent potentially preventable complications of obstetric care.

2. **Direct transfers from the hospital where childbirth occurred to another facility.**

Direct transfers were defined as readmissions that met both of the following criteria:
a. The time from discharge to readmission was (a) 0-1 days if the disposition from the index (childbirth) hospitalization was reported as another acute care hospital (05) or (b) 0 days if the disposition was reported as any other site (including "routine" [01], "residential care facility" [08],

[6] Romano PS, Rainwater JA, Schembri ME, et al. *OSHPD Postpartum Maternal Outcomes Validation Study – Final Report.*

[7] When risk-adjusted cesarean readmission rates (excluding patients with missing or invalid SSNs) were previously compared with risk-adjusted cesarean complication rates (including all eligible patients) across hospitals, a highly significant but modest correlation was noted (weighted $r=0.29$, $p < 0.0001$). The comparable correlation between risk-adjusted vaginal delivery readmission rates and complication rates across hospitals was weaker but still significant (weighted $r=0.12$, $p = 0.03$). In addition, no hospital-level correlation was found between risk-adjusted readmission rates and the percentage of patients with missing or invalid SSNs. These findings suggest that excluding patients with missing or invalid SSNs did not bias the results of the readmissions analysis. OSHPD's previous technical report provides additional details about the impact of missing social security numbers.

"prison/jail" [09], "against medical advice" [10], "died" [11], "home health service" [12], or "other" [13]); and
b. Readmission occurred at a different facility than the index (childbirth) hospitalization.

Several other definitions of direct transfers were tested. If the discharge disposition had been limited to "acute care hospital," then transfers involving patients transported by private automobile and patients with misreported discharge dispositions might have been miscounted as readmissions. If the time from discharge to readmission for transfers had been limited to 0 days, several readmissions with a reported source of "acute care hospital" would not have been identified as transfers (presumably because the patient was admitted to the receiving facility in the early morning, one day after an evening transfer from the referring facility).

Direct transfers were excluded because they may not represent complications of obstetric care. A woman may be transferred solely because her child requires neonatal intensive care and she is not yet ready for discharge, perhaps because she had a cesarean delivery. In addition, a woman may be transferred because the hospital that performed the delivery is not equipped to treat a complication that requires inpatient care. Transferring a patient in this situation would be appropriate care and should not be penalized.

3. **Readmissions with principal diagnoses unrelated to obstetric care.**

Based only on review of the ICD-9-CM code book and a summary of relevant clinical literature, OSHPD's Clinical Expert Panel selected the following principal diagnoses as those most likely to be complications related to prior obstetric care.

Postpartum endometritis, sepsis, cellulitis (category 1)
038.xx – Septicemia
614.xx – Salpingitis, oophoritis, parametritis, PID, pelvic cellulitis/peritonitis
615.0 – Acute inflammatory diseases of the uterus
615.9 – Unspecified inflammatory diseases of the uterus
670.0x – Major puerperal infection
672.0x, 780.6 – Pyrexia of unknown origin
682.x – Cellulitis
789.0 – Abdominal pain

Postpartum hemorrhage and retained products (category 2)
666.0x – Third-stage hemorrhage
666.1x – Other immediate postpartum hemorrhage
666.2x – Delayed and secondary postpartum hemorrhage
667.0x – Retained placenta without hemorrhage
667.1x – Retained portions of placenta/membranes, without hemorrhage

Postpartum wound infection (category 3)
674.1x – Disruption of cesarean wound
674.2x – Disruption of perineal wound
674.3x – Other complications of obstetric surgical wounds
998.3 – Disruption of operation wound
998.51 – Infected postoperative seroma
998.59 – Other postoperative infection/abscess

Postpartum urinary tract infection (category 4)
646.60/2/4 – Infections of genitourinary tract in (related to) pregnancy
590.1x – Acute pyelonephritis
590.2 – Renal and perinephric abscess

590.80 – Pyelonephritis, unspecified
590.9 – Infection of kidney, unspecified
595.0 – Acute cystitis
599.0 – Urinary tract infection, site not specified

Postpartum mastitis (category 5)
675.xx – Infections of the breast and nipple associated with childbirth
611.0 – Inflammatory disease of breast

Postpartum thromboembolic complications (category 6)
671.4x – Deep phlebothrombosis, postpartum
673.2x – Obstetrical blood clot embolism
415.1x – Pulmonary embolism and infarction
451.1x – Phlebitis/thrombophlebitis of deep veins of lower extremities
451.2 – Phlebitis/thrombophlebitis of lower extremities, unspecified
451.81 – Phlebitis/thrombophlebitis of iliac vein
451.9 – Phlebitis/thrombophlebitis of unspecified site
453.2 - Other venous embolism and thrombosis of vena cava
453.8 – Other venous embolism/thrombosis of other specified veins
453.9 – Other venous embolism/thrombosis of unspecified site

Obstetric trauma or injury (category 7)
665.3x-665.9x – Other obstetrical trauma, except uterine rupture

Anesthesia complications (category 8)
349.0 – Lumbar puncture reaction

Miscellaneous complications (category 9)
997.x – Surgical complications

Upon review of the actual distribution of principal diagnoses among readmissions that were otherwise eligible for inclusion, the research team recommended adding several related, but uncommon, principal diagnoses to the list of those considered related to prior obstetric care. Table A.8 shows the actual number and frequency of readmissions, by principal diagnosis, in the study data set. When a 3-digit or 4-digit root code such as 038.xx is listed in the table, readmissions with any 5-digit principal diagnosis under this root code were captured, but only the 5-digit codes specifically named in the table were actually represented in the data set. Readmissions with any other principal diagnosis were not counted in the analysis of postpartum readmissions.

Table A.8: Number and frequency of readmissions ordered by principal diagnosis

Principal Diagnosis	Category	N	% of readmissions
038.xx SEPTICEMIA			
0380 STREPTOCOCCAL SEPTICEMIA	1	2	0.031
0383 ANAEROBIC SEPTICEMIA	1	1	0.016
03840 GRAM-NEG SEPTICEMIA NOS	1	1	0.016
03842 E COLI SEPTICEMIA	1	5	0.079
03843 PSEUDOMONAS SEPTICEMIA	1	1	0.016
03849 GRAM-NEG SEPTICEMIA NEC	1	2	0.031
0389 SEPTICEMIA NOS	1	10	0.157
04089 BACTERIAL DISEASES NEC	1	2	0.031
2752 DIS MAGNESIUM METABOLISM	9	2	0.031

Principal Diagnosis	Category	N	% of readmissions
276.x DISORDER FLUID ELECTROLYTE BALANCE			
2760 HYPEROSMOLALITY	9	1	0.016
2761 HYPOSMOLALITY	9	1	0.016
2765 HYPOVOLEMIA	9	11	0.173
2767 HYPERPOTASSEMIA	9	1	0.016
2768 HYPOPOTASSEMIA	9	1	0.016
2800 CHR BLOOD LOSS ANEMIA	2	1	0.016
2809 IRON DEFIC ANEMIA NOS	2	1	0.016
2851 ACUTE POSTHEMORRHAG ANEMIA	2	4	0.063
2859 ANEMIA NOS	2	4	0.063
3490 LUMBAR PUNCTURE REACTION	8	18	0.283
415.1x PULM EMBOLISM/INFARCTION			
41511 IATROGEN PULM EMB/INFARCT	6	1	0.016
41519 PULM EMBOL/INFARCT NEC	6	12	0.189
451.1x PHLEBITIS/THROMBO DEEP VEIN LOWER EXT			
45111 FEMORAL VEIN PHLEBITIS	6	1	0.016
45119 DEEP PHLEBITIS-LEG NEC	6	2	0.031
4512 PHLEBITIS/THROMBOPHLEB LOWER EXT NOS	6	0	0.000
45189 THROMBOPHLEBITIS NEC	6	1	0.016
4519 PHLEBITIS/THROMBOPHLEBITIS NOS	6	0	0.000
4532 VENOUS EMB/THROMB VENA CAVA	6	0	0.000
4538 VENOUS THROMBOSIS NEC	6	22	0.346
4539 VENOUS THROMBOSIS NOS	6	2	0.031
567.x PERITONITIS			
5672 SUPPURAT PERITONITIS NEC	1	5	0.079
5678 PERITONITIS NEC	1	3	0.047
590.1x ACUTE PYELONEPHRITIS			
59010 ACUTE PYELONEPHRITIS NOS	4	47	0.739
5902 RENAL PERINEPHRIC ABSCESS	4	0	0.000
590.8x OTHER PYELONEPHRITIS NOS			
59080 PYELONEPHRITIS NOS	4	27	0.424
5909 INFEC KIDNEY NOS	4	0	0.000
5950 ACUTE CYSTITIS	4	0	0.000
5959 CYSTITIS NOS	4	2	0.031
5990 URIN TRACT INFECTION NOS	4	25	0.393
611.0 INFLAMM DISEASE BREAST	5	0	0.000
614.x INFLAMM DISEASE OF OVARY, FALLOPIAN TUBE, PELVIC CELLULAR TISSUE, PERITONEUM			
6140 AC SALPINGO-OOPHORITIS	1	1	0.016
6141 CHR SALPINGO-OOPHORITIS	1	1	0.016
6142 SALPINGO-OOPHORITIS NOS	1	6	0.094
6143 ACUTE PARAMETRITIS	1	4	0.063
6144 CHRONIC PARAMETRITIS	1	1	0.016
6146 FEM PELVIC PERITON ADHES	1	3	0.047
6149 FEM PELV INFLAM DIS NOS	1	6	0.094
6150 ACUTE UTERINE INFLAMMATION	1	16	0.251
6159 UTERINE INFLAM DIS NOS	1	30	0.472
6164 ABSCESS OF VULVA NEC	3	1	0.016
646.6x INFECTION GU TRACT PREG			
64662 GU INFECTION-DELIV W P/P	4	2	0.031
64663 GU INFECTION-ANTEPARTUM	4	4	0.063
64664 GU INFECTION-POSTPARTUM	4	416	6.539

Principal Diagnosis	Category	N	% of readmissions
64782 INFECT DIS NEC-DEL W P/P	1	1	0.016
64784 INFECT DIS NEC-POSTPART	1	56	0.880
64794 INFECT NOS-POSTPARTUM	1	4	0.063
64822 ANEMIA-DEL W P/P COMPL	2	0	0.000
64824 ANEMIA-POSTPARTUM	2	55	0.865
664.xx TRAUMA PERINEUM VULVA DURING DEL			
66404 DEL W 1 DEG LAC-POSTPART	7	1	0.016
66434 DEL W 4 DEG LAC-POSTPART	7	1	0.016
66454 PERIN HEMATOMA-POSTPART	7	13	0.204
665.3X-665.9X OTHER OBSTET TRAUMA			
66534 LACER OF CERVIX-POSTPART	7	2	0.031
66544 HIGH VAGINAL LAC-POSTPAR	7	1	0.016
66554 INJ PELV ORG NEC-POSTPAR	7	4	0.063
66564 DAMAGE PELVIC JT-POSTPAR	7	6	0.094
66574 PELVIC HEMATOMA-POSTPART	7	17	0.267
666.0x THIRD-STAGE HEMORRHAGE			
66602 THRD-STAGE HEM-DEL W P/P	2	1	0.016
66604 THIRD-STAGE HEM-POSTPART	2	46	0.723
666.1x OTHER IMMED POSTPART HEMORRHAGE			
66614 POSTPART HEM NEC-POSTPAR	2	31	0.487
666.2x DELAYED SEC POSTPART HEMORRHAGE			
66620 DELAY P/PART HEM-UNSPEC	2	1	0.016
66624 DELAY P/PART HEM-POSTPAR	2	628	9.871
667.xx RETAIN PLACENTA MEMBRANES W/OUT HEMORRHAGE			
66704 RETAIN PLAC NOS-POSTPART	2	2	0.031
66714 RETAIN PROD CONCEPT-POSTPAR	2	38	0.597
668.xx COMPLIC ADMIN ANESTH SEDATION L&D			
66804 PULM COMPLICAT-POSTPART	8	7	0.110
66814 HEART COMPLIC-POSTPART	8	1	0.016
66824 CNS COMPL IN DEL-POSTPAR	8	3	0.047
66884 ANESTH COMPL-POSTPARTUM	8	61	0.959
66894 ANESTH COMPL-POSTPARTUM	8	1	0.016
670.0x MAJOR PUERPERAL INFECTION			
67000 MAJOR PUERP INFECT-UNSPEC	1	1	0.016
67002 MAJOR PUERP INF-DEL P/P	1	5	0.079
67004 MAJOR PUERP INF-POSTPART	1	1337	21.015
671.4x DEEP PHLEBOTHROMB POSTPAR			
67144 DEEP VEIN THROMB-POSTPAR	6	116	1.823
672.0x PYREXIA UNKNOWN ORIGIN PUERPERIUM			
67202 PUERP PYREXIA-DEL W P/P	1	1	0.016
67204 PUERP PYREXIA-POSTPARTUM	1	93	1.462
673.2x OBSTETRIC BLOOD CLOT EMBOLISM			
67324 PULM EMBOL NOS-POSTPART	6	60	0.943
674.1x DISRUPT CESAREAN WOUND			
67414 DISRUPT C-SECT-POSTPART	3	59	0.927
674.2X DISRUPT PERINEAL WOUND			
67424 DISRUPT PERINEUM-POSTPAR	3	20	0.314
674.3X OTHER COMPL OBSTET SURG WOUNDS			
67430 OB SURG COMPL NEC-UNSPEC	3	1	0.016
67432 OB SURG COMPL-DEL W P/P	3	1	0.016
67434 OB SURG COMP NEC-POSTPAR	3	584	9.180

Principal Diagnosis	Category	N	% of readmissions
675.xx INFECT BREAST NIPPLE CHILDBRTH	5	0	0.000
681.xx CELLULITIS ABSCESS FINGER TOE			
68101 FELON	1	1	0.016
682.xx OTHER CELLULITIS AND ABSCESS			
6820 CELLULITIS OF FACE	1	6	0.094
6821 CELLULITIS OF NECK	1	1	0.016
6822 CELLULITIS OF TRUNK	1	12	0.189
6823 CELLULITIS OF ARM	1	5	0.079
6824 CELLULITIS OF HAND	1	1	0.016
6825 CELLULITIS OF BUTTOCK	1	3	0.047
6826 CELLULITIS OF LEG	1	12	0.189
7806 FEVER	1	11	0.173
789.0x ABDOMINAL PAIN			
78900 ABDMNAL PAIN UNSPEC SITE	1	11	0.173
78901 ABDMNAL PAIN RT UPR QUAD	1	5	0.079
78902 ABDMNAL PAIN LFT UPR QUAD	1	1	0.016
78903 ABDMNAL PAIN RT LWR QUAD	1	29	0.456
78904 ABDMNAL PAIN LT LWR QUAD	1	2	0.031
78906 ABDMNAL PAIN EPIGASTRIC	1	2	0.031
78907 ABDMNAL PAIN GENERALIZED	1	2	0.031
78909 ABDMNAL PAIN OTH SPEC SITE	1	9	0.141
7907 BACTEREMIA	1	1	0.016
968.x POIS-OTHER CNS DEPRESS ANESTH			
9680 POIS-CNS MUSCLE DEPRESS	8	1	0.016
9685 POIS-TOPIC/INFILT ANESTH	8	1	0.016
997.xx COMPLIC AFFECT SPEC BODY SYSTEMS NEC			
99709 SURG COMP NERV SYSTM NEC	9	1	0.016
9971 SURG COMPL-HEART	9	1	0.016
9972 SURG COMP-PERI VASC SYST	9	4	0.063
9973 SURG COMPLIC-RESPIR SYST	9	1	0.016
9974 SURG COMP-DIGESTV SYSTEM	9	20	0.314
9975 SURG COMPL-URINARY TRACT	9	3	0.047
99811 HEMORRHAGE COMPLIC PROC	2	2	0.031
99812 HEMATOMA COMPLIC PROC	3	9	0.141
99813 SEROMA COMPLICTING PROC	3	4	0.063
9982 ACCIDENTAL OP LACERATION	7	3	0.047
9983 POSTOP WOUND DISRUPTION	3	4	0.063
998.5x POSTOP INFECTION			
99851 INFECTED POSTOP SEROMA	3	13	0.204
99859 OTHER POSTOP INFECTION	3	67	1.053
9986 PERSIST POSTOP FISTULA	3	1	0.016
99883 NON-HEALING SURGICAL WOUND	3	1	0.016
9993 INFEC COMPL MED CARE NEC	1	1	0.016
Total readmissions		6362	100

Primary and repeat cesarean deliveries

Finally, OSHPD is also reporting primary and repeat risk-adjusted cesarean delivery rates, because these rates were estimated as part of the overall analysis of other outcomes, and because this information may be useful to women and their family members who are interested in reducing the likelihood of cesarean delivery.

The primary cesarean delivery rate is defined as the number of cesarean deliveries among primiparous, low-risk women, divided by the total number of primiparous, low-risk women who experience childbirth at an eligible facility. Primiparous women are those who have not had a prior birth after 20 weeks of gestation. Miscarriages and therapeutic abortions (terminations of pregnancy) count as prior births only if they occurred after 20 weeks of gestation, which is relatively unusual. Low-risk women have a singleton gestation at full term (i.e., at least 37 weeks of gestation) with normal fetal presentation (i.e., vertex).

The repeat cesarean delivery rate is defined as the number of cesarean deliveries among multiparous low-risk women who have had at least one prior cesarean delivery, divided by the total number of such women who experience childbirth at an eligible facility. Miscarriages and therapeutic abortions (terminations of pregnancy) count as prior births only if they occurred after 20 weeks of gestation, which is relatively unusual. Low-risk women have a singleton gestation at full term (i.e., at least 37 weeks of gestation) with normal fetal presentation (i.e., vertex). Some advocate limiting the repeat cesarean delivery rate to women who had the most common type of uterine incision for their prior cesarean delivery (i.e., low transverse), because women with other types of uterine incision may be at higher risk of uterine rupture during labor. However, the type of prior uterine incision is not available in either the California Patient Discharge Data Set or the linked birth certificate file.

The vaginal-birth-after-cesarean or VBAC rate is not being reported separately, but it is simply the complement of the repeat cesarean delivery rate, or 100 minus that rate (in percentages).

Although there are many important reasons why cesarean delivery may be necessary, even among women who are defined as low-risk, it has long been recognized that cesarean delivery rates are higher overall than the optimal level from the public health perspective. In recent years, some pregnant women with no clinical reason for cesarean delivery have begun to request this type of delivery, and some physicians honor these requests. Given that the cost difference between cesarean and vaginal delivery is modest, there is probably a role for patient preferences and physician discretion in choosing the mode of delivery for individual low-risk women. On the other hand, some women feel very strongly about giving birth in a safe but natural manner to reduce the risk of postoperative complications and to promote better bonding with their newborn infant. Accordingly, OSHPD is reporting primary and repeat cesarean rates as a way to inform consumer decision-making, without placing any quality label on the findings for individual hospitals.

To select potential risk factors for primary and repeat cesarean delivery, which should be included in the risk-adjustment procedure, a comprehensive review of the published medical literature was undertaken. This review was performed using the MEDLINE bibliographic database from 1985 through 2002. Studies from outside the US and studies limited to atypical populations (e.g., patients who had unusual procedures or risk factors) were not abstracted. To simplify this search, given the huge number of published papers on risk factors for cesarean delivery, abstracts were reviewed to identify studies that involved large, population-based data sets. Case series from individual hospitals or from groups of self-identified volunteer hospitals were not reviewed. Primary attention was given to studies that were based on existing data sets similar to those available in California.

Table A.9 shows the risk factors for primary cesarean delivery that were identified in prior studies using large, population-based databases in the United States. The first row indicates the first author and year of publication of each study. The second row indicates the primary data source and the subpopulation on which the model was constructed. For example, the California Perinatal Quality of Care Collaborative (CPQCC) merged data from the Vital Statistics file (i.e., birth certificates) and the Patient Discharge Data Set (referred to generically as an HCUP database, after the Healthcare Cost and Utilization Project sponsored by the Agency for Healthcare Research and Quality, which aggregates data of this type from 38 states). Aron et al. (1998) performed parallel analyses on the Cleveland Health Quality Choice data set, which was generated through detailed abstraction of clinical data from medical records and Vital Statistics data covering the same area. Roohan et al. analyzed Medicaid and commercially insured women separately using data from New York State. Keeler et al. analyzed nulliparous and multiparous women separately using data from Washington. The numbers displayed represent odds ratios from multivariable logistic regression models. To save space, only the point estimates for these odd ratios are shown; nearly all were statistically significant due to the huge size of the data sets. In general, the findings were quite consistent across studies, except that some risk factors were only available in some data sets. In addition, some researchers deliberately excluded factors for which risk estimates would be difficult to interpret because the underlying diagnosis either lacks clear diagnostic criteria (e.g., hyperemesis) or is made after the patient experiences an adverse outcome (e.g., meconium staining).

Table A.10 shows the risk factors for primary cesarean delivery that were identified in prior studies using large, population-based databases in the United States. The first row indicates the first author and year of publication of each study. The second row indicates the primary data source and the subpopulation on which the model was constructed. The numbers displayed represent odds ratios from multivariable logistic regression models. To save space, only the point estimates for these odd ratios are shown; nearly all were statistically significant due to the huge size of the data sets. Note that the dependent variable in Keeler et al.'s analysis was vaginal birth after cesarean delivery, so the odds ratios are in the opposite direction from those reported by other investigators, who used repeat cesarean delivery as the outcome variable.

Table A.11 shows the same risk factors identified in Tables A.9 and A.10, but with additional annotation to indicate whether the variable was available and/or used in this analysis of cesarean rates, perineal lacerations, and postpartum maternal readmissions.

Table A.9: Risk Factors for Primary Cesarean Delivery in Prior Studies Using Large Databases

Risk factor	Specification	CPQCC 2003		OSHPD 1996		Bailit 1999, 2002		Aron 1998		Peaceman 2002	Glantz 1999	Roohan 2001		Keeler 1997		
		CA HCUP+VS	Source	CA HCUP	Source	IL VS	WA VS	CHQC	VS	IL HCUP+VS	NY VS	NY Medicaid	NY Comm	WA nullip	WA multip	Source
Birth weight	1,001-2,500	0.58	VS							1.15	1.76	2.70	2.20	Excluded	Excluded	VS
	2,501-2,750	0.39	VS													
	2,751-3,000	0.40	VS													
	3,000-3,250	Ref	VS							Ref						
	3,251-3,500	0.52	VS													
	3,501-3,750	0.65	VS													
	3,751-4,000	0.88	VS													
	4,001-4,250	1.28	VS													
	4,251-4,500	1.76	VS													
	4,501-4,750	2.57	VS							2.23		2.40	2.10			
	4,751-5,000	3.42	VS													
	over 5000	4.47	VS													
	Macrosomia			4.70	Index			2.08	2.13		1.91					
	BW (continuous)													0.39	0.09	VS
	BW squared													0.25	0.24	VS
Maternal Age	under 20	0.73	VS			0.63		1.08	1.11	0.58	0.34	0.80	0.90			
	20 to under 25	Ref	VS					1.51	1.55	Ref		1.30	1.70			
	25 to under 30	1.36	VS			Ref		1.94	2.13		Ref					
	30 to under 35	1.78	VS					1.89	2.25	1.23						
	35 to under 40	2.55	VS			1.72		2.43	3.02	1.54	1.49	2.10	2.40			
	40 or older	3.98	VS					3.20	4.73					0.36	0.61	VS/PDD
	Years (continuous)			1.01	Index		1.1							0.31	0.18	VS/PDD
Maternal Education	Did not Complete High School	Ref	VS			0.83						Ref	Ref			
	High School Degree	1.06	VS			Ref						0.80	1.10			
	At least some College	0.92	VS			0.90						0.90	0.90			
	Unknown	0.94	VS			Excluded						1.00	0.90			
Race/Ethnicity	Non-Hispanic White	Ref	VS	Ref		Ref	Ref					Ref	Ref			
	Hispanic	1.28	VS	0.85	Index	1.12	1.2					1.30	1.50			
	African American	1.59	VS	0.90	Index	1.22	1.4					1.60	1.70			
	Native American	1.19	VS													
	South East Asian	1.12	VS	0.39	Index		1.1					0.60	1.10			
	Other Asian	1.06	VS													
	Other Race	1.39	VS				1.1									

Risk factor	Specification	CPQCC 2003		OSHPD 1996		Bailit 1999, 2002		Aron 1998		Peaceman 2002	Glantz 1999	Roohan 2001		Keeler 1997		
		CA HCUP+VS	Source	CA HCUP	Source	IL VS	WA VS	CHQC	VS	IL HCUP+VS	NY VS	NY Medicaid	NY Comm	WA nullip	WA multip	Source
Gestational Age	24-29 weeks					1.51	2.5	0.92	1.17	0.65						
	30-36 weeks					1.26	1.6			1.13						
	37-40 weeks					Ref	Ref			Ref						
	>=41 weeks					1.75	1.6			1.87						
	Postterm Gestation	1.85	PDD	2.74	Either			3.00	2.01					0.22	0.24	
	Weeks (continuous)													0.06	0.02	VS
	WIC, Medicaid, TANF						1.2									
Public Benefits	None					0.50										
Prenatal Care	Any					1.73								0.10	0.23	VS
Medical Risks	Grand multiparity (absence)	Excluded												Excluded	0.26	VS
Parity	Nulliparous					4.98	5.2	5.39	6.51	6.08	3.56	3.10	4.50	All	Excluded	VS
	Interpartum interval (x<1.5 or x>4 yrs)	Excluded												Excluded	0.20	VS
	Weight gain >50 lbs								1.44		1.50					
Maternal obesity	Maternal obesity (prepregnancy>250 lbs)								2.39		1.85					
	Weight gain (continuous)													0.02	0.02	VS
	Weight gain squared													0.07	0.08	VS
	Diabetes	1.66	VS/PDD	1.70	Either		1.4*	2.70	1.84	3.89	2.09	1.60	1.30	0.82	0.39	VS/PDD
Clinical Factors	Chronic Hypertension	1.06	PDD	4.07			1.6†	2.06	1.46	2.14		1.10	1.50	0.37	0.19	VS/PDD
	Pregnancy-Induced Hypertension	2.31	PDD	2.62	Either			1.64	2.27			1.70	1.60	0.37	0.19	VS/PDD
	Prolonged rupture of membranes	1.74	PDD		Either			1.78	1.31							
	Placenta Previa	8.53	VS/PDD	25.5-59.0	Index	38.79¶	25.4¶	14.84	60.45	38.91	61.94			1.13	1.64	VS/PDD
	Placenta Abruptio	5.52	VS/PDD	5.48	Index	38.79¶	25.4¶	8.11	15.10	3.45	3.99	5.70	3.40	1.13	1.64	VS/PDD
	Oligohydramnios	2.04	PDD	2.52	Either		1.6†	2.35	3.22	1.60	1.62			0.54	0.48	VS/PDD
	Chorioamnionitis	3.85	Not spec	7.28	Index			2.31			2.93			0.61	0.77	VS/PDD
	Genital Herpes	6.24	PDD	47.11	Index		1.4§	3.93	3.30					1.64	2.15	VS/PDD
	Breech	Excluded		174.50	Index	38.79¶	25.4¶	58.23	111.08	40.28	64.90	9.40	6.10	Excluded	Excluded	VS/PDD
	Congenital uterine abnormality			4.53	Either											

Risk factor	Specification	CPQCC 2003		OSHPD 1996		Bailit 1999, 2002		Aron 1998		Peaceman 2002	Glantz 1999	Roohan 2001		Keeler 1997		
		CA HCUP+VS	Source	CA HCUP	Source	IL VS	WA VS	CHQC	VS	IL HCUP+VS	NY VS	NY Medicaid	NY Comm	WA nullip	WA multip	Source
Clinical factors	**Drug abuse**			0.61	Either											
	Eclampsia			6.21	Index		1.4*	3.07	3.30			2.00	2.20			
	Hyperemesis			1.28	Prior											
	Fetal distress			5.33	Index											
	Genitourinary infection			1.67	Index											
	Multiple gestation	Excluded		7.37	Either	5.86	3.7	1.21	Excluded	2.89	2.16			Excluded	Excluded	
	Occiput posterior			9.73	Index											
	Polyhydramnios			2.90	Either		1.6†	2.21	3.22	6.77	1.62			0.54	0.48	VS/PDD
	Preeclampsia			3.84	Either		1.6†	3.07	3.30	2.27	2.59	2.00	2.20			
	Premature labor			0.74	Index			0.77			0.61					
	Previous cesarean	Excluded		31.67	Either	Excluded	Excluded	Excluded	Excluded	37.46	18.72	Excluded	Excluded	Excluded	Excluded	VS/PDD
	Prolapsed cord			10.77	Index	38.79¶	25.4¶	12.59	19.96		8.85			1.13	1.64	VS/PDD
	Rheumatologic disorder			1.61	Either											
	Poor fetal growth			1.80	Either			1.92								
	Stillbirth	Excluded		0.27	Either	Excluded	Excluded	Excluded	Excluded		Excluded	Excluded	Excluded			
	Transverse lie	Excluded		37.90	Index	38.79¶	25.4¶	21.61	111.08	40.28	64.90			Excluded	Excluded	VS/PDD
	Incompetent cervix						1.4*	1.39								
	Severe maternal comorbidities						1.4*	1.81								
	Maternal anemia						1.4§	1.35								
	Meconium staining							1.55	1.57		1.37					
	Fetal abnormalities							1.73	1.56-12.56					0.30	0.56	VS/fetal
	Other antepartum hemorrhage						1.6†	2.81	0.88							
	Maternal seizures								11.45							
	Tobacco use							0.99	1.01		1.23					
	Maternal height <64 inches										1.76					
	Fetal sex										1.21			0.10	0.07	VS

Table A.10: Risk Factors for Repeat Cesarean Delivery in Prior Studies Using Large Databases

Risk factor	Specification	Keeler 1997		Landon 2005	JCAHO 2002
		WA prior C/S	Source	MFMU cesarean registry	HCUP
Birth weight	**1,001-2,500**	Excluded	VS	0.88	
	2,501-2,750				
	2,751-3,000				
	3,000-3,250				
	3,251-3,500				
	3,501-3,750				
	3,751-4,000				
	4,001-4,250				
	4,251-4,500				
	4,501-4,750				
	4,751-5,000				
	over 5000				
	Macrosomia			1.82	2.28
	Birth weight (continuous)	0.04	VS		
	Birth weight squared	0.17	VS		
Maternal Age	**under 20**				
	20 to under 25				
	25 to under 30				
	30 to under 35				
	35 to under 40				
	40 or older	0.48	VS/PDD		
	Years (continuous)	0.01	VS/PDD		1.03
Date	**Date of admission**	-0.08	VS		
Maternal Education	**Did not Complete High School**				
	High School Degree				
	At least some College				
	Unknown				
Race/Ethnicity	**Non-Hispanic White**				
	Hispanic				
	African American				
	Native American				
	South East Asian				
	Other Asian				
	Other Race				

Risk factor	Specification	Keeler 1997		Landon 2005	JCAHO 2002
		WA prior C/S	Source	MFMU cesarean registry	HCUP
Gestational Age	24-29 weeks				
	30-36 weeks				
	37-40 weeks				
	>=41 weeks			1.64	
	Weeks (continuous)		VS		
Public Benefits	WIC, Medicaid, TANF				
Prenatal Care	None				
Medical Risks	Any	-0.07	VS		
Parity	Grand multiparity (absence)	0.33	VS		
	Nulliparous	Excluded	VS	Excluded	Excluded
	Previous vaginal delivery			0.24	
	Previous VBAC			0.21	
	Previous cesarean <2 yrs			1.43	
	Interpartum interval (x<1.5 or x>4 yrs)	0.15	VS		
Maternal obesity	Weight gain >50 lbs				
	Maternal obesity (prepregnancy>250 lbs)				Considered, not used
	Weight gain (continuous)	0.04	VS		
	Weight gain squared	0.12	VS		
Clinical factors	Diabetes	0.58	VS/PDD	1.23	1.74
	Chronic Hypertension	0.19	VS/PDD	1.23	1.22
	Pregnancy-Induced Hypertension	0.19	VS/PDD		1.22
	Prolonged rupture of membranes				
	Placenta Previa	0.33	VS/PDD		3.76
	Placenta Abruptio	0.33	VS/PDD		Considered, not used
	Oligohydramnios	0.11	VS/PDD		Considered, not used
	Chorioamnionitis	Omitted	VS/PDD		Considered, not used
	Genital Herpes	0.63	VS/PDD		Considered, not used
	Breech	0.62	VS/PDD		3.65
	Congenital uterine abnormality				3.46
	Drug abuse				
	Eclampsia				1.82

Risk factor	Specification	Keeler 1997		Landon 2005	JCAHO 2002
		WA prior C/S	Source	MFMU cesarean registry	HCUP
Clinical factors	Hyperemesis				
	Fetal distress				x
	Genitourinary infection				
	Multiple gestation	Excluded			x
	Occiput posterior				
	Polyhydramnios	0.11	VS/PDD		1.77
	Preeclampsia				1.82
	Premature labor				
	Prolapsed cord	0.33	VS/PDD		x
	Rheumatologic disorder			1.23	
	Poor fetal growth				
	Stillbirth				
	Transverse lie	0.62	VS/PDD		3.65
	Incompetent cervix				3.46
	Prior transverse scar			1.41	
	Epidural anesthesia			0.37	
	Severe maternal comorbidities			1.23	
	Maternal anemia				
	Meconium staining				
	Fetal abnormalities	0.03	VS/fetal		
	Other antepartum hemorrhage				2.51
	Maternal seizures			1.23	
	Tobacco use				x
	Maternal height <64 inches				
	Disproportion				9.78
	Failure to progress				1.69
	Fetal sex	0.06	VS		
Previous cesarean indication	Dystocia			2.94	
	Nonreassuring FWB			1.96	
	Other			1.49	
	Malpresentation			Ref	
Labor characteristics	Induced labor			2.00	
	Augmented labor			1.47	
	Cervix <4 cm at admission			2.56	

Table A.11: Summary of All Risk Factors Identified from Literature Review and Rationale for Chosen Specifications

Risk factor	Specification	Considered	Variable name	Source	Rationale for chosen specification
Birth weight	**1,001-2,500**	Rejected			Used birth weight instead (fewer degrees of freedom)
	2,501-2,750	Rejected			Used birth weight instead (fewer degrees of freedom)
	2,751-3,000	Rejected			Used birth weight instead (fewer degrees of freedom)
	3,000-3,250	Rejected			Used birth weight instead (fewer degrees of freedom)
	3,251-3,500	Rejected			Used birth weight instead (fewer degrees of freedom)
	3,501-3,750	Rejected			Used birth weight instead (fewer degrees of freedom)
	3,751-4,000	Rejected			Used birth weight instead (fewer degrees of freedom)
	4,001-4,250	Rejected			Used birth weight instead (fewer degrees of freedom)
	4,251-4,500	Rejected			Used birth weight instead (fewer degrees of freedom)
	4,501-4,750	Rejected			Used birth weight instead (fewer degrees of freedom)
	4,751-5,000	Rejected			Used birth weight instead (fewer degrees of freedom)
	over 5000	Rejected			Used birth weight instead (fewer degrees of freedom)
	Macrosomia	Rejected			Used birth weight instead (better estimation)
	BW (continuous)	Used	bthwghtKG	VS	
	BW squared	Used	bthwghtKGSQ	VS	
Maternal Age	**under 20**	Rejected			Used actual age instead (fewer degrees of freedom)
	20 to under 25	Rejected			Used actual age instead (fewer degrees of freedom)
	25 to under 30	Rejected			Used actual age instead (fewer degrees of freedom)
	30 to under 35	Rejected			Used actual age instead (fewer degrees of freedom)
	35 to under 40	Rejected			Used actual age instead (fewer degrees of freedom)
	40 or older	Rejected			Used actual age instead (fewer degrees of freedom)
	Years (continuous)	Used	ageyrsM	OSHPD	Alternative from VS is mage; differences were evaluated and found to be trivial
Maternal Education	**Did not Complete High School**	Used		VS	
	High School Degree	Used		VS	
	At least some College	Used		VS	
	Unknown	Used	meduVSgrp	VS	Used maternal education categories
Race/Ethnicity	**Non-Hispanic White**	Used		VS	
	Hispanic	Used		VS	
	African American	Used		VS	
	Native American	Used		VS	
	South East Asian	Used		VS	
	Other Asian	Used (A/PI)		VS	
	Other Race	Used(Oth/UK)	raceVSgrp	VS	Used recategorized version of mrace and msporig, standard method
Gestational Age	**24-29 weeks**	Rejected			

Risk factor	Specification	Considered	Variable name	Source	Rationale for chosen specification
	30-36 weeks	Rejected			
	37-40 weeks	Rejected			
	>=41 weeks	Rejected			
	Postterm Gestation	Rejected			Used gestational age as multi-category variable instead
	Weeks (continuous)	Used	gestgrpn	VS	Used categorical version of gest (completed weeks of gestation)
Public Benefits	**WIC, Medicaid, TANF**	Not available			
Prenatal Care	**None**	Inappropriate			Likely endogenous (prenatal care is probably associated with inpatient quality)
Medical Risks	**Any**	Rejected			Better specified using separate risk factors
Parity	**Grand multiparity (absence)**	Used	parity	VS	Should equal lbd_lbl (sum of living and dead children) with missing removed
	Nulliparous	Stratified			
	Interpartum interval (x<1.5 or x>4 yrs)	Used	llbmthsN	VS	Tested other groupings (<1.5 yrs, 1.5-2.5 yrs, 2.5-4 yrs, 4-6 yrs, >6 yrs)
Maternal obesity	**Weight gain >50 lbs**	Not available			
	Maternal obesity (prepregnancy>250 lbs)	Not available			ICD-9-CM code for obesity severely underreported
	Weight gain (continuous)	Not available			
	Weight gain squared	Not available			
Clinical factors	**Diabetes**	Used	diabetesfnl	VS/OSHPD	
	Chronic Hypertension	Used	hyptenfnl	VS/OSHPD	Collapse categories 1 (mild) and 2 (severe) because 2 is too rare
	Pregnancy-Induced Hypertension	Used	hyptenfnl	VS/OSHPD	Collapse categories 1 (mild) and 2 (severe) because 2 is too rare
	Prolonged rupture of membranes	Inappropriate			Likely endogenous (prolonged rupture may be a marker of inpatient quality)
	Placenta Previa	Used	plcntprevfnl	VS/OSHPD	
	Placenta Abruptio	Used	abruptiofnl	VS/OSHPD	
	Oligohydramnios	Used	olighydr	OSHPD	
	Chorioamnionitis	Used	amnionitisOSHPfnl	OSHPD	
	Genital Herpes	Used	herpesfnl	VS/OSHPD	
	Breech	Used	breechfnl	VS/OSHPD	
	Congenital uterine abnormality	Used	conguter	OSHPD	
	Abnormal/fibroid uterus	Used	abuterusFib	OSHPD	

Risk factor	Specification	Considered	Variable name	Source	Rationale for chosen specification
Clinical factors	**Drug abuse**	Unreliable			Poorly reported - sensitivity <60% in prior studies
	Eclampsia	Used	eclampfnl	VS/OSHPD	
	Hyperemesis	Unreliable			No longer clinically relevant at the time of delivery
	Fetal distress	Inappropriate			Likely endogenous (labeling of fetal distress may be associated with quality)
	Genitourinary infection	Unreliable			Poorly reported - sensitivity <60% in prior studies
	Multiple gestation	Used	multgestfnl	VS/OSHPD	
	Occiput posterior	Used	occipost	OSHPD	
	Polyhydramnios	Unreliable			Poorly reported - sensitivity <60% in prior studies
	Preeclampsia	Used	preeclampfnl	VS/OSHPD	Collapsed categories 2 and 3, because 2 is too rare
	Premature labor	Rejected			Used gestational age instead, which is more precise
	Previous cesarean	Stratified			
	Prolapsed cord	Used	prolapse	VS/OSHPD	
	Rheumatologic disorder	Too rare			
	Poor fetal growth	Rejected			Used birth weight and gestational age instead, which are more precise
	Stillbirth	Excluded			
	Transverse lie	Used	transvrs	OSHPD	
	Incompetent cervix	No logic			No clinical link to adverse postpartum maternal outcomes
	Severe maternal comorbidities	Unreliable			Poorly reported - sensitivity <60% in prior studies
	Maternal anemia	Unreliable			Poorly reported - sensitivity <60% in prior studies
	Meconium staining	Not available			
	Fetal abnormalities	Unreliable			Linked birth certificates would be preferred data source
	Other antepartum hemorrhage	Unreliable			Poorly reported - sensitivity <60% in prior studies
	Maternal seizures	Too rare			
	Tobacco use	Unreliable			Poorly reported - sensitivity <60% in prior studies
	Maternal height <64 inches	Not available			
	Fetal sex	No logic			No clinical link to adverse postpartum maternal outcomes

Risk Factors in the Model

Risk factors were defined as characteristics or conditions that existed at the time of admission and that possibly influenced the patient outcome. Hospitals in which a high percentage of the patients had these risk factors (that is, hospitals with a high risk case mix) would be likely to have higher laceration rates or readmission rates, apart from the quality of care provided.

In this study, risk factors were defined as characteristics or conditions that probably existed at the time of admission and that are thought to influence patient outcomes, based on prior research and expert clinical opinion. Conditions that typically arise later in a hospital stay were treated as complications rather than risk factors. Four sets of risk factors were examined.

The first set of risk factors are demographic characteristics such as maternal education, race, and age. The second set are hospitalization characteristics such as the year and quarter of childbirth and the source of admission. The third set represents clinical characteristics, including both chronic illnesses of the patient and complications of the current pregnancy itself. All clinical risk factors were based on the diagnoses and procedures listed on discharge abstracts and coded using ICD-9-CM, or selected data elements from the infant birth certificate. Each patient discharge abstract includes a principal diagnosis and principal procedure, plus as many as 24 other diagnosis codes and as many as 20 other procedure codes.

The demographic variables that were obtained from patient discharge abstracts were race/ethnicity and age. Maternal education was obtained from the vital statistics file. All patients in the current study were female.

Several measures describing the hospitalization were available from patient discharge abstracts: year and quarter of childbirth, expected principal source of payment, source of admission, and type of admission. The first two of these variables were tested in risk-adjustment models. Temporal trends in the occurrence of both perineal lacerations and postpartum maternal readmissions were anticipated. Expected source of payment was used as a crude indicator of socioeconomic status, but proved not to be a consistent predictor of maternal outcomes (after adjusting for other factors). Source of admission was uninformative because obstetric patients are very rarely admitted from the emergency department; they are generally triaged directly to the labor and delivery unit. Type of admission could not be used as a predictor of delivery outcomes because nearly all deliveries are assigned to just one category (“unscheduled”).

Method for Selecting Clinical Risk Factors

With the assistance of a Clinical Expert Panel that included expert physicians and other health professionals, a list of potential clinical risk factors for perineal lacerations and postpartum readmissions was developed.

All potential risk factors were adapted to ICD-9-CM by reviewing all volumes of ICD-9-CM; the American Hospital Association's *ICD-9-CM Coding Handbook*; *Coding Clinic for ICD-9-CM*; and other publications for coding professionals. These adaptations were reviewed by two coding experts. Finally, the numbers of cases and the laceration rate or readmission rate associated with each ICD-9-CM diagnosis were examined to ensure that no potential clinical risk factors had been omitted. During this process, many potential clinical risk factors were redefined to capture differences in risk more precisely. The following overall criteria were used to select risk factors:

Prevalence. Extremely rare conditions (e.g., less than 0.1% prevalence) were not considered for inclusion in the model as potential clinical risk factors, because it would have been impossible to estimate their contribution to patient risk. Some moderately rare conditions were considered as

potential clinical risk factors but were eliminated during the model development process described below.

Ability to define using ICD-9-CM or birth certificate data. Risk factors for which there were no corresponding ICD-9-CM codes or birth certificate fields were not included because they could not be identified from the available data.

Confidence that the condition was likely to have been present when the patient was admitted to the hospital. Conditions likely to have developed after admission, such as surgical wound infections, were not considered as potential clinical risk factors. However, the timing of secondary diagnoses is not always clear. Conditions that could have developed either before or after admission were retained for further examination. Coding of diagnosis timing ("condition present at admission") was not considered in this study because it was not available for the entire study period and there was uncertainty regarding the accuracy of reporting in 2000. In addition, most of the relevant obstetric codes have a 5-digit structure that identifies each diagnosis on a childbirth record as either "delivered, with or without mention of antepartum condition" (5^{th} digit=1) or "delivered, with mention of postpartum complication" (5^{th} digit=2). This coding structure was used when appropriate.

Clinical importance. Conditions were not included in the list of potential clinical risk factors if they seemed obviously trivial. During the model development process, risk factors that were not associated with the outcomes of interest were identified and removed, so that the resulting models would be more parsimonious.

Use of Linked Antepartum Records

The analysis of readmissions involved linkage of antepartum as well as postpartum records, as described above. About 6.5% of vaginal deliveries and 9.8% of cesarean deliveries in this analysis had one or more antepartum hospitalizations within 39 weeks prior to delivery. Clinical risk factors were defined somewhat differently according to whether there were any prior hospitalizations:

Risk factors that may be diagnosed anytime during pregnancy and typically do not resolve before delivery, such as hypertension, preeclampsia, and gestational diabetes, were identified from either the index delivery hospitalization or antepartum hospitalizations. If there were no antepartum hospitalizations, then the index abstract alone was used to identify these factors.

Risk factors that represent chronic diseases, such as asthma and seizure disorder, were identified from either the index delivery hospitalization or antepartum hospitalizations. If there were no antepartum hospitalizations, then the index abstract alone was used to identify these risk factors.

Risk factors that are typically diagnosed around the time of delivery, or may resolve before delivery when diagnosed earlier, were identified exclusively from the index delivery record. For example, chorioamnionitis and premature rupture of membranes occur at or after the onset of labor. These conditions were ascertained only from the index delivery record, because they would not resolve before delivery and miscoding would be the most likely explanation if they appeared on an antepartum record but not on the delivery record. Malpresentation (e.g., breech or transverse presentation) may be diagnosed at any time during pregnancy, but may be manually or spontaneously corrected. Therefore, malpresentation also counted as a risk factor only if it was coded on the delivery record.

Risk factors that inherently represent antepartum conditions were identified exclusively from antepartum hospitalizations. Only two risk factors fit this description: threatened abortion and vomiting/dehydration. Both were coded as absent if there were no antepartum hospitalizations; both virtually never appeared on index delivery records.

Two final risk factors (anemia and genitourinary infection) were coded in two versions, depending whether the diagnosis was identified on the index delivery record or only on an antepartum record. This approach was intended to distinguish between cases that were still active at the time of delivery and those that had resolved with treatment earlier in the pregnancy.

Definitions of Risk Factors

The fifth digit of the obstetric diagnosis code indicates the episode of care: 0 represents "unspecified," 1 and 2 represent "delivered" ("with or without mention of antepartum condition," and "with mention of postpartum complication," respectively); 3 represents "antepartum," and 4 represents "postpartum." Although coding guidelines state that no record should have obstetric diagnoses with a fifth digit of 1 or 2 **and** diagnoses with a fifth digit of 3 or 4, this combination was seen in about 0.3% of vaginal delivery records and 0.5% of cesarean delivery records. This is a significant problem because numerous risk factors for adverse outcomes are defined using the fifth digit. To prevent miscoding by hospitals from biasing the ascertainment of risk factors, all index delivery records with invalid combinations of fifth digits were corrected.[8]

Table A.12 shows the ICD-9-CM definitions of the final set of risk factors used in risk-adjustment models for postpartum readmissions, perineal lacerations, or both.

Stratified Analyses

Women who are experiencing childbirth for the first time ("primiparous") are at greatly increased risk of various antepartum and intrapartum complications, including preeclampsia and eclampsia, prolonged labor, shoulder dystocia, and unexpected cesarean delivery. Women who have previously experienced childbirth with vaginal delivery have a far lower risk of problems during labor and hence a lower risk of unexpected cesarean delivery. By contrast, women who have previously experienced childbirth with cesarean delivery are often encouraged or required to have elective repeat cesarean delivery, which is scheduled at a mutually convenient time but which confers an increased risk of certain postpartum complications. For this reason, all subsequent analyses were stratified according to whether the woman had "no prior deliveries," "one or more prior vaginal deliveries, and no cesarean deliveries," or "one or more prior cesarean deliveries."

[8] This was done by changing all fifth digits of "3" to "1", and all fifth digits of "4" to "2", on both vaginal and cesarean delivery records.

Table A.12: Definitions of risk factors used in risk-adjustment models

Variable Name	Description	Valid Value[9]	ICD-9-CM codes (if applicable)[10]
DDyrqtr	Year and quarter of delivery	19994-20014	
_brthid	Unique identifier of birth record (scrambled)	Number and character combination of length 15	
Abruptiofnl	Abruption VS/OSHPD[11]	1=yes, 0=no	641.2x
abuterusFib	Abnormal uterus	1=yes, 0=no	654.41,654.43,654.3x,654.1x,218.xx
ageyrsM	Mom's age in years at admission		
amnionitisOSHPfnl	Amnionitis OSHPD only	1=yes, 0=no	658.4, 659.3
Breechfnl	Breech VS/OSHPD	1=yes, 0=no	652.2x, 652.4x, 652.6, 669.6x
Bthwght	Uncorrected Birthweight (grams)		
bthwghtSQ	Square of Birthweight (grams)		
Conguter	Congenital uterine abnormality	1=yes, 0=no	752.2,752.3, 654.0x
Cordprlpse	Cord prolapse (VS only)[12]		
Delmode	Mode of delivery	1=c-section, 0=vaginal	
Diabetesfnl	Diabetes VS/OSHPD	2=severe,1=mild, 0=no	S:250.1x-250.9x, 357.2, 366.41. M:362.0x, 250.0x, 648.0x, 648.8x, 790.2x
diag1-diag24	other (secondary) diagnoses	icd-9-cm codes required if reported	
diag_p	principal diagnosis	icd-9-cm code required	
eclampfnl	Eclampsia VS/OSHPD	1=yes, 0=no	642.6x
forceps	Forceps in delivery	1=yes, 0=no	72.0x-72.4x, 72.6x, 72.51, 72.53
gest	Length of gestation in days		
gestge42wk	Gestational age more than 42 weeks	1=yes, 0=no	
gestgrpn	Gestational age groups	24-42	
herpesfnl	Herpes VS/OSHPD	1=yes, 0=no	054.10, 054.11, 054.12, 054.19, 054.79, 054.8, 054.9

[9] Missing numeric fields are indicated with periods ('.').

[10] ICD-9-CM codes are listed only for diagnoses that were ascertained from OSHPD's Patient Discharge Data Set.

[11] "VS/OSHPD" means that this risk factor was ascertained from either OSHPD's Patient Discharge Data Set (using the listed set of ICD-9-CM codes) or from the Department of Public Health's Vital Statistics birth file.

[12] "VS only" means that this risk factor could only be ascertained from the Department of Public Health's Vital Statistics birth file, because it was either unavailable or unreliable in OSHPD data.

Variable Name	Description	Valid Value[9]	ICD-9-CM codes (if applicable)[10]
hospidM	Mom's hospital ID	six digits: first two=01-58 (valid county code), last four=unique	
hyptenfnl	Hypertension VS/OSHPD	2=severe,1=mild, 0=no	S: 402.xx--404.xx, 429.3, 642.2x, M: 401.xx,405.xx,642.0x,642.1x,642.7x,642.9x
llbmthsN	Months from last live birth		
mageOSHPgrp	Mothers age group (OSHPD)	1=age < 20, 2=Age 20-24,3=Age 25-29,4=Age 30-34,5=Age 35-39, 6=Age 40 +	
meduVSgrp	Mothers education group (VS only)	1=years of education< 12, 2=years of education 12-15, 3=years of education 16+, 9=Uknown	
multgestfnl	Multiple gestation	1=yes, 0=no	651.xx, 660.5x, 652.6x, 662.3x, v27.2x--v27.7x
occipost	Occipitoposterior	1=yes, 0=no	660.3x
olighydr	Olighydramnios	1=yes, 1=no	658.0x
parity	Parity after birth	1,2,3,4,5+,"Unknown"	
plcntprevfnl	Placenta previa VS/OSHPD	1=yes, 0=no	641.0x, 641.1x
prdlac	Estimated Probability	between 0-1	
preeclampfnl	Preeclampsia VS/OSHPD	2=severe,1=mild, 0=no	S: 642.7x, 642.5x. M: 642.3x, 642.4x
priorcsec_fnl	Prior C-section	1=yes, 0=no	654.2x
proc_p	principal procedure	icd-9-cm codes required if reported	
prolapsefnl	Prolapse	1=yes, 0=no	663.0x
prolnglab	Prolonged labor (>20 hours) (VS only)	1=yes, 0=no	662.0x-662.2x
raceVSgrp	Race group (VS only)	1=nH White,2=NH African American, 3=NH American Indian, 4-6=NH Other Asian/PI,7=NH South East Asian,8=Hispanic, 9=Unknown/other	
readmit	Readmission	1=yes, 0=no	
thrdorfrthlac	Third or 4th degree laceration	1=yes, 0=no	664.2x-664.3x
transvrs	Transverse or oblique presentation	1=yes, 0=no	652.3x
vacuum	Vacuum delivery	1=yes, 0=no	72.7x
validgest	Valid gestational age	Y='yes', N='No'	

Table A.13 shows the overall prevalence of each risk factor among women with no prior deliveries (the first stratum), along with its crude association with mode of delivery. Table A.14 shows the crude readmission rates for women with and without each of these risk factors, among women with no prior deliveries. Tables A.15 and A.16 show same data for women with one or more prior vaginal deliveries and no cesarean deliveries. Tables A.17 and A.18 show the same data for women with one or more prior cesarean deliveries. Finally, Table A.19 shows the overall prevalence of each risk factor among all women with vaginal deliveries, along with the perineal laceration rates for women with and without each of these risk factors.

Table A.13: Demographic and Clinical Characteristics of Women with No Prior Deliveries, with Unadjusted Cesarean Delivery Rates (N=334,265)

	Mode of Delivery					
	Vaginal (n=250,343)		C-section (n=83,922)		Total (n=334,265)	
	N	%	N	%	N	%
Maternal age at delivery (years)						
< 20	56459	84	10751	16	67210	20.1
20-24	67634	79	17689	21	85323	25.5
25-29	57974	75	19517	25	77491	23.2
30-34	46669	69	20732	31	67401	20.2
35-39	18210	61	11745	39	29955	9.0
≥ 40	3397	49	3488	51	6885	2.1
Maternal race						
White	102232	74	36163	26	138395	41.4
Hispanic	88752	77	27144	23	115896	34.7
African American	17118	74	6152	26	23270	7.0
American Indian	1162	76	372	24	1534	0.5
Other Asian/Pacific Islander	29911	74	10648	26	40559	12.1
South East Asian	9346	77	2737	23	12083	3.6
Other or unknown	1822	72	706	28	2528	0.8
Mothers education group VS only						
Education level < 12	45141	80	11419	20	56560	16.9
Education level 12-15	127944	75	42200	25	170144	50.9
Education level 16 or more	73679	72	29119	28	102798	30.8
Unknown	3579	75	1184	25	4763	1.4
Birth weight (grams)						
< 1000	1022	52	934	48	1956	0.6
1000-1499	769	38	1236	62	2005	0.6
1500-1999	1954	50	1921	50	3875	1.2
2000-2499	9419	69	4143	31	13562	4.1
2500-2999	46222	80	11497	20	57719	17.3
3000-3999	174114	77	51777	23	225891	67.6
>=4000	16843	58	12414	42	29257	8.8
Congenital uterine abnormality						
No	250123	75	83077	25	333200	99.7
Yes	220	21	845	79	1065	0.3
Occiput posterior						
No	248312	76	78978	24	327290	97.9
Yes	2031	29	4944	71	6975	2.1
Transverse or oblique presentation						

	Mode of Delivery					
	Vaginal (n=250,343)		C-section (n=83,922)		Total (n=334,265)	
	N	%	N	%	N	%
no	249893	75	82269	25	332162	99.4
Yes	450	21	1653	79	2103	0.6
Gestational age						
Invalid gestation	10839	75	3670	25	14509	4.3
Gestational age < 24 weeks	382	87	59	13	441	0.1
Gestational age = 24 weeks	107	54	92	46	199	0.1
Gestational age = 25 weeks	135	49	142	51	277	0.1
Gestational age = 26 weeks	143	51	139	49	282	0.1
Gestational age = 27 weeks	132	39	206	61	338	0.1
Gestational age = 28 weeks	146	37	246	63	392	0.1
Gestational age = 29 weeks	223	45	270	55	493	0.1
Gestational age = 30 weeks	369	53	323	47	692	0.2
Gestational age = 31 weeks	464	54	389	46	853	0.3
Gestational age = 32 weeks	798	59	562	41	1360	0.4
Gestational age = 33 weeks	1362	64	768	36	2130	0.6
Gestational age = 34 weeks	2633	69	1211	32	3844	1.1
Gestational age =35-41weeks	211536	76	68195	24	279731	83.7
Gestational age = 42+ weeks	21074	73	7650	27	28724	8.6
Year and quarter of delivery						
19994	29873	76	9601	24	39474	11.8
20001	29523	76	9492	24	39015	11.7
20002	29707	75	9687	25	39394	11.8
20003	31066	76	10070	24	41136	12.3
20004	29704	75	9856	25	39560	11.8
20011	28190	75	9646	25	37836	11.3
20012	27788	74	9789	26	37577	11.2
20013	30049	74	10495	26	40544	12.1
20014	14443	73	5286	27	19729	5.9
Diabetes VS/OSHPD						
No	241190	76	77844	24	319034	95.4
Mild	8265	62	5014	38	13279	4.0
Severe	888	45	1064	55	1952	0.6
Hypertension VS/OSHPD						
No	247842	75	81788	25	329630	98.6
Yes	2501	54	2134	46	4635	1.4
Preeclampsia VS/OSHPD						
No	235296	76	73029	24	308325	92.2
Mild	14243	60	9606	40	23849	7.1
Severe	804	38	1287	62	2091	0.6
Eclampsia VS/OSHPD						
No	250059	75	83570	25	333629	99.8

	Mode of Delivery					
	Vaginal (n=250,343)		C-section (n=83,922)		Total (n=334,265)	
	N	%	N	%	N	%
Yes	284	45	352	55	636	0.2
Abnormal uterus						
No	249463	76	79673	24	329136	98.5
Yes	880	17	4249	83	5129	1.5
Placenta previa VS/OSHPD						
No	250031	75	82625	25	332656	99.5
Yes	312	19	1297	81	1609	0.5
Abruptio placenta						
No	249179	75	82183	25	331362	99.1
Yes	1164	40	1739	60	2903	0.9
Olighydramnios						
No	244420	75	79452	25	323872	96.9
Yes	5923	57	4470	43	10393	3.1
Amnionitis OSHPD only						
No	244839	76	77625	24	322464	96.5
Yes	5504	47	6297	53	11801	3.5
Herpes VS/OSHPD						
No	249283	75	82461	25	331744	99.2
Yes	1060	42	1461	58	2521	0.8
Prolapsefnl						
No	249956	75	83294	25	333250	99.7
Yes	387	38	628	62	1015	0.3
Breech presentation						
No	249427	79	68157	21	317584	95.0
Yes	916	5	15765	95	16681	5.0
Multiple gestation						
No	249380	75	81742	25	331122	99.1
Yes	963	31	2180	69	3143	0.9

Table A.14: Demographic and Clinical Characteristics of Women with No Prior Deliveries, with Unadjusted Postpartum Maternal Readmission Rates (N=334,265**)**

	Readmission After Delivery				
	No		Yes		Total
	(n=332531)		(n=1734)		(334,265)
	N	%	N	%	
Maternal age at delivery (years)					
< 20	66823	99	387	1	67210
20-24	84882	99	441	1	85323
25-29	77121	100	370	0	77491
30-34	67087	100	314	0	67401
35-39	29790	99	165	1	29955
≥ 40	6828	99	57	1	6885
Maternal race					
White	137691	99	704	1	138395
Hispanic	115307	99	589	1	115896
African American	23086	99	184	1	23270
American Indian	1526	99	8	1	1534
Other Asian/Pacific Islander	40367	100	192	0	40559
South East Asian	12034	100	49	0	12083
Other or unknown	2520	100	8	0	2528
Mothers education group					
Education level < 12	56228	99	332	1	56560
Education level 12-15	169207	99	937	1	170144
Education level 16 or more	102352	100	446	0	102798
Unknown	4744	100	19	0	4763
Birth weight (grams)					
< 1000	1927	99	29	1	1956
1000-1499	1978	99	27	1	2005
1500-1999	3848	99	27	1	3875
2000-2499	13484	99	78	1	13562
2500-2999	57454	100	265	0	57719
3000-3999	224772	100	1119	1	225891
>=4000	29068	99	189	1	29257
Preeclampsia VS/OSHPD					
No	306847	100	1478	0	308325
Mild	25684	99	256	1	25940
Hypertension VS/OSHPD	327950	99	1680	1	329630
No					
Yes	4581	99	54	1	4635
Amnionitis OSHPD only					
No	320830	99	1634	1	322464
Yes	11701	99	100	1	11801
Occiput posterior					
No	325628	99	1662	1	327290
Yes	6903	99	72	1	6975
Number of Prior Admissions					

	Readmission After Delivery				
	No		Yes		Total
	(n=332531)		(n=1734)		(334,265)
	N	%	N	%	
0	310685	100	1532	0	312217
1	18456	99	156	1	18612
2	2606	99	37	1	2643
3+	784	99	9	1	793
Type of Delivery					
Cesarean	83174	99	748	1	83922
Vaginal	249357	100	986	0	250343

Table A.15: Demographic and Clinical Characteristics of Women with One or More Prior Vaginal Deliveries, and No Cesarean Deliveries, with Unadjusted Cesarean Delivery Rates (N=408,339**)**

	Mode of Delivery					
	Vaginal (n=371,583)		C-section (n=36,756)		Total (408,339)	
	N	%	N	%	N	%
Maternal age at delivery (years)						
< 20	14031	94	844	6	14875	3.6
20-24	77571	94	5214	6	82785	20.3
25-29	101737	92	8646	8	110383	27.0
30-34	105035	91	10952	9	115987	28.4
35-39	59603	88	8240	12	67843	16.6
≥ 40	13606	83	2860	17	16466	4.0
Maternal race						
White	135194	91	13153	9	148347	36.3
Hispanic	159382	91	15566	9	174948	42.8
African American	27166	88	3649	12	30815	7.5
American Indian	2078	91	204	9	2282	0.6
Other Asian/Pacific Islander	33987	92	3074	8	37061	9.1
South East Asian	11643	93	854	7	12497	3.1
Other or unknown	2133	89	256	11	2389	0.6
Mothers education group VS only						
Education level < 12	85188	91	8576	9	93764	23.0
Education level 12-15	202866	91	20147	9	223013	54.6
Education level 16 or more	78728	91	7468	9	86196	21.1
Unknown	4801	89	565	11	5366	1.3
Birth weight (grams)						
< 1000	903	55	754	46	1657	0.4
1000-1499	690	39	1070	61	1760	0.4
1500-1999	2012	52	1846	48	3858	0.9
2000-2499	9473	74	3377	26	12850	3.1
2500-2999	49292	89	5939	11	55231	13.5
3000-3999	265289	94	17893	6	283182	69.3
>=4000	43924	88	5877	12	49801	12.2
Congenital uterine abnormality						
No	371435	91	36568	9	408003	99.9
Yes	148	44	188	56	336	0.1
Occiput posterior						
No	369856	91	35648	9	405504	99.3
Yes	1727	61	1108	39	2835	0.7
Transverse or oblique presentation						
no	371098	91	34788	9	405886	99.4
Yes	485	20	1968	80	2453	0.6

	Mode of Delivery					
	Vaginal (n=371,583)		C-section (n=36,756)		Total (408,339)	
	N	%	N	%	N	%
Gestational group						
Invalid gestation	21730	90	2298	10	24028	5.9
Gestational age < 24 weeks	318	81	74	19	392	0.1
Gestational age = 24 weeks	90	55	73	45	163	0.0
Gestational age = 25 weeks	113	51	107	49	220	0.1
Gestational age = 26 weeks	94	38	153	62	247	0.1
Gestational age = 27 weeks	109	40	162	60	271	0.1
Gestational age = 28 weeks	110	34	215	66	325	0.1
Gestational age = 29 weeks	201	44	259	56	460	0.1
Gestational age = 30 weeks	331	51	320	49	651	0.2
Gestational age = 31 weeks	580	59	404	41	984	0.2
Gestational age = 32 weeks	955	65	513	35	1468	0.4
Gestational age = 33 weeks	1813	71	733	29	2546	0.6
Gestational age = 34 weeks	3590	77	1068	23	4658	1.1
Gestational age =35-41weeks	311047	92	27890	8	338937	83.0
Gestational age = 42+ weeks	30502	92	2487	8	32989	8.1
Year and quarter of delivery						
19994	43021	91	4107	9	47128	11.5
20001	42926	91	4094	9	47020	11.5
20002	43963	91	4250	9	48213	11.8
20003	45948	91	4412	9	50360	12.3
20004	44111	91	4314	9	48425	11.9
20011	41943	91	4267	9	46210	11.3
20012	42519	91	4439	9	46958	11.5
20013	45498	91	4599	9	50097	12.3
20014	21654	91	2274	10	23928	5.9
Diabetes VS/OSHPD						
no	353085	91	33026	9	386111	94.6
Mild	16632	84	3160	16	19792	4.8
Severe	1866	77	570	23	2436	0.6
Hypertension VS/OSHPD						
No	367961	91	35721	9	403682	98.9
Yes	3622	78	1035	22	4657	1.1
Preeclampsia VS/OSHPD						
No	360381	92	33430	8	393811	96.4
Mild	10540	79	2818	21	13358	3.3
Severe	662	57	508	43	1170	0.3
Eclampsia VS/OSHPD						
no	371341	91	36643	9	407984	99.9
Yes	242	68	113	32	355	0.1
Abnormal uterus						
No	370400	91	35400	9	405800	99.4

	Mode of Delivery					
	Vaginal (n=371,583)		C-section (n=36,756)		Total (408,339)	
	N	%	N	%	N	%
Yes	1183	47	1356	53	2539	0.6
Placenta previa VS/OSHPD						
No	370986	91	34754	9	405740	99.4
Yes	597	23	2002	77	2599	0.6
Abruptio placenta						
No	369391	91	34958	9	404349	99.0
Yes	2192	55	1798	45	3990	1.0
Olighydramnios						
No	365957	91	35157	9	401114	98.2
Yes	5626	78	1599	22	7225	1.8
Amnionitis OSHPD only						
No	369302	91	35450	9	404752	99.1
Yes	2281	64	1306	36	3587	0.9
Herpes VS/OSHPD						
No	370294	91	35982	9	406276	99.5
Yes	1289	62	774	38	2063	0.5
Prolapsefnl						
No	371015	91	35953	9	406968	99.7
Yes	568	41	803	59	1371	0.3
Breech presentation						
No	369595	94	23963	6	393558	96.4
Yes	1988	13	12793	87	14781	3.6
Multiple gestation						
No	368278	92	31640	8	399918	97.9
Yes	3305	39	5116	61	8421	2.1
Parity prior to index birth						
1	198892	91	19261	9	218153	53.4
2	102402	91	9709	9	112111	27.5
3	41990	91	4357	9	46347	11.4
4	15487	90	1807	10	17294	4.2
5+	12409	89	1549	11	13958	3.4
Unknown	403	85	73	15	476	0.1
Interval between previous and index delivery (years)						
0-1.5	40890	87	6101	13	46991	11.5
1.5-2.5	88557	94	5576	6	94133	23.1
2.5-4	96597	93	7298	7	103895	25.4
4-6	70082	92	6316	8	76398	18.7
6+	75457	87	11465	13	86922	21.3

Table A.16: Demographic and Clinical Characteristics of Women with One or More Prior Vaginal Deliveries, and No Cesarean Deliveries, with Unadjusted Postpartum Maternal Readmission Rates (N=408,339**)**

	Readmission After Delivery				
	No		Yes		Total
	(n=406,787)		(n=1,552)		(408,339)
	N	%	N	%	
Maternal age at delivery (years)					
< 20	14805	100	70	0	14875
20-24	82479	100	306	0	82785
25-29	109964	100	419	0	110383
30-34	115566	100	421	0	115987
35-39	67578	100	265	0	67843
> 40	16395	100	71	0	16466
Maternal race					
White	147783	100	564	0	148347
Hispanic	174301	100	647	0	174948
African American	30652	99	163	1	30815
American Indian	2263	99	19	1	2282
Other Asian/Pacific Islander	36945	100	116	0	37061
South East Asian	12457	100	40	0	12497
Other or unknown	2386	100	3	0	2389
Mothers education group					
Education level < 12	93417	100	347	0	93764
Education level 12-15	222105	100	908	0	223013
Education level 16 or more	85922	100	274	0	86196
Unknown	5343	100	23	0	5366
Birth weight (grams)					
< 1000	1631	98	26	2	1657
1000-1499	1737	99	23	1	1760
1500-1999	3812	99	46	1	3858
2000-2499	12786	100	64	1	12850
2500-2999	55017	100	214	0	55231
3000-3999	282197	100	985	0	283182
>=4000	49607	100	194	0	49801
Preeclampsia VS/OSHPD					
No	392373	100	1438	0	393811
Mild	14414	99	114	1	14528
Hypertension VS/OSHPD	402174	100	1508	0	403682
No					
Yes	4613	99	44	1	4657
Amnionitis OSHPD only					
No	403232	100	1520	0	404752
Yes	3555	99	32	1	3587
Occiput posterior					

	Readmission After Delivery				
	No (n=406,787)		Yes (n=1,552)		Total (408,339)
	N	%	N	%	
No	403966	100	1538	0	405504
Yes	2821	100	14	0	2835
Number of Prior Admissions					
0	379558	100	1334	0	380892
1	22636	99	149	1	22785
2	3486	99	45	1	3531
3+	1107	98	24	2	1131
Type of Delivery					
C	36429	99	327	1	36756
V	370358	100	1225	0	371583
Parity prior to index birth					
1	217374	100	779	0	218153
2	111689	100	422	0	112111
3	46166	100	181	0	46347
4	17200	99	94	1	17294
5+	13886	99	72	1	13958
Unknown	472	99	4	1	476

Table A.17: Demographic and Clinical Characteristics of Women with One or More Prior Cesarean Deliveries, with Unadjusted Cesarean Delivery Rates (n=118,136)

	Mode of Delivery				
	Vaginal		C-section		Total
	(n=29,829)		(n=88,307)		(N=118,136)
	N	%	N	%	
Maternal age at delivery (years)					
< 20	604	27	1646	73	2250
20-24	4523	27	12131	73	16654
25-29	7812	28	20491	72	28303
30-34	9407	25	27845	75	37252
35-39	6077	23	20660	77	26737
≥ 40	1406	20	5534	80	6940
Maternal race					
White	10339	24	32222	76	42561
Hispanic	13092	26	37787	74	50879
African American	2641	25	7793	75	10434
American Indian	139	22	488	78	627
Other Asian/Pacific Islander	2617	25	7928	75	10545
South East Asian	826	35	1528	65	2354
Other or unknown	175	24	561	76	736
Mothers education group VS only					
Education level < 12	7062	27	19014	73	26076
Education level 12-15	15747	25	48341	75	64088
Education level 16 or more	6574	25	19845	75	26419
Unknown	446	29	1107	71	1553
Birth weight (grams)					
< 1000	206	29	496	71	702
1000-1499	131	17	646	83	777
1500-1999	257	19	1087	81	1344
2000-2499	991	24	3192	76	4183
2500-2999	4352	26	12246	74	16598
3000-3999	20649	26	58599	74	79248
>=4000	3243	21	12041	79	15284
Congenital uterine abnormality					
No	29772	25	87621	75	117393
Yes	57	8	686	92	743
Occiput posterior					
No	29672	25	87632	75	117304
Yes	157	19	675	81	832
Transverse or oblique presentation					
no	29764	25	87025	75	116789
Yes	65	5	1282	95	1347
Gestational group					

	Mode of Delivery				
	Vaginal (n=29,829)		C-section (n=88,307)		Total (N=118,136)
	N	%	N	%	
Invalid gestation	1769	26	5116	74	6885
Gestational age < 24 weeks	77	57	59	43	136
Gestational age = 24 weeks	23	29	55	71	78
Gestational age = 25 weeks	24	22	83	78	107
Gestational age = 26 weeks	27	25	81	75	108
Gestational age = 27 weeks	33	23	109	77	142
Gestational age = 28 weeks	35	20	143	80	178
Gestational age = 29 weeks	33	18	152	82	185
Gestational age = 30 weeks	57	21	221	80	278
Gestational age = 31 weeks	75	21	284	79	359
Gestational age = 32 weeks	148	26	422	74	570
Gestational age = 33 weeks	216	23	709	77	925
Gestational age = 34 weeks	383	24	1213	76	1596
Gestational age =35-41weeks	24465	25	74012	75	98477
Gestational age = 42+ weeks	2464	30	5648	70	8112
Year and quarter of delivery	3844	29	9624	71	13468
19994					
20001	3843	28	9912	72	13755
20002	3866	28	10137	72	14003
20003	3907	27	10662	73	14569
20004	3545	26	10222	74	13767
20011	3267	25	10062	75	13329
20012	3153	23	10345	77	13498
20013	3010	21	11548	79	14558
20014	1394	19	5795	81	7189
Diabetes VS/OSHPD					
no	27846	26	79544	74	107390
Mild	1758	20	7253	80	9011
Severe	225	13	1510	87	1735
Hypertension VS/OSHPD					
No	29459	25	86245	75	115704
Yes	370	15	2062	85	2432
Preeclampsia VS/OSHPD					
No	28858	26	83503	74	112361
Mild	910	18	4165	82	5075
Severe	61	9	639	91	700
Eclampsia VS/OSHPD					
no	29805	25	88177	75	117982
Yes	24	16	130	84	154
Abnormal uterus					
No	29713	26	84697	74	114410
Yes	116	3	3610	97	3726
Placenta previa VS/OSHPD					
No	29772	26	86928	74	116700
Yes	57	4	1379	96	1436

	Mode of Delivery				
	Vaginal (n=29,829)		C-section (n=88,307)		Total (N=118,136)
	N	%	N	%	
Abruptio placenta					
No	29556	25	87101	75	116657
Yes	273	18	1206	82	1479
Olighydramnios					
No	29319	25	86667	75	115986
Yes	510	24	1640	76	2150
Amnionitis OSHPD only					
No	29268	25	87110	75	116378
Yes	561	32	1197	68	1758
Herpes VS/OSHPD					
No	29676	25	87607	75	117283
Yes	153	18	700	82	853
Prolapsefnl					
No	29760	25	88031	75	117791
Yes	69	20	276	80	345
Breech presentation					
No	29626	27	81189	73	110815
Yes	203	3	7118	97	7321
Multiple gestation					
No	29675	26	86434	74	116109
Yes	154	8	1873	92	2027
Parity prior to index birth					
1	12052	20	47515	80	59567
2	9393	27	24830	73	34223
3	4730	33	9745	67	14475
4	1888	35	3449	65	5337
5+	1735	39	2710	61	4445
Unknown	31	35	58	65	89
Interval between previous and index delivery (years)					
0-1.5	3315	27	9153	73	12468
1.5-2.5	7301	27	19440	73	26741
2.5-4	7725	26	21853	74	29578
4-6	5707	25	16908	75	22615
6+	5781	22	20953	78	26734

Table A.18: Demographic and Clinical Characteristics of Women with One or More Prior Cesarean Deliveries, with Unadjusted Postpartum Maternal Readmission Rates (n=118,136)

	Mode of Delivery				
	No		Yes		Total
	(n=117,393)		(n=743)		(118,136)
	N	%	N	%	
Maternal age at delivery (years)					
< 20	2242	100	8	0	2250
20-24	16536	99	118	1	16654
25-29	28132	99	171	1	28303
30-34	37028	99	224	1	37252
35-39	26569	99	168	1	26737
> 40	6886	99	54	1	6940
Maternal race					
White	42319	99	242	1	42561
Hispanic	50569	99	310	1	50879
African American	10320	99	114	1	10434
American Indian	618	99	9	1	627
Other Asian/Pacific Islander	10498	100	47	0	10545
South East Asian	2342	99	12	1	2354
Other or unknown	727	99	9	1	736
Mothers education group					
Education level < 12	25889	99	187	1	26076
Education level 12-15	63687	99	401	1	64088
Education level 16 or more	26279	99	140	1	26419
Unknown	1538	99	15	1	1553
Birth weight (grams)					
< 1000	684	97	18	3	702
1000-1499	764	98	13	2	777
1500-1999	1327	99	17	1	1344
2000-2499	4151	99	32	1	4183
2500-2999	16493	99	105	1	16598
3000-3999	78800	99	448	1	79248
>=4000	15174	99	110	1	15284
Preeclampsia VS/OSHPD					
No	111673	99	688	1	112361
Mild	5720	99	55	1	5775
Hypertension VS/OSHPD	114996	99	708	1	115704
No					
Yes	2397	99	35	1	2432
Amnionitis OSHPD only					
No	115660	99	718	1	116378
Yes	1733	99	25	1	1758
Occiput posterior					
No	116563	99	741	1	117304
Yes	830	100	2	0	832

	Mode of Delivery				
	No (n=117,393)		Yes (n=743)		Total (118,136)
	N	%	N	%	
Number of Prior Admissions					
0	108433	99	637	1	109070
1	7267	99	69	1	7336
2	1229	98	26	2	1255
3+	464	98	11	2	475
Type of Delivery					
Cesarean	87701	99	606	1	88307
Vaginal	29692	100	137	0	29829
Parity after birth					
1	59219	99	348	1	59567
2	34011	99	212	1	34223
3	14385	99	90	1	14475
4	5286	99	51	1	5337
5+	4404	99	41	1	4445
Unknown	88	99	1	1	89

Table A.19: Demographic and Clinical Characteristics of Women with and without 3rd and 4th degree Perineal Lacerations at Vaginal Delivery (N=658,017)

	No (n=626,558)		Yes (n=31,459)		Total	
	N	**%**	**N**	**%**	**N**	**%**
Maternal age at delivery (years)						
< 20	68240	95	3548	5	71788	10.9
20-24	144856	96	6188	4	151044	23.0
25-29	160451	95	8504	5	168955	25.7
30-34	153981	95	8590	5	162571	24.7
35-39	81011	95	3885	5	84896	12.9
≥ 40	18019	96	744	4	18763	2.9
Maternal race						
White	235107	94	13692	6	248799	37.8
Hispanic	253380	97	9039	3	262419	39.9
African American	46123	97	1310	3	47433	7.2
American Indian	3274	97	116	3	3390	0.5
Other Asian/Pacific Islanders	61266	92	5535	8	66801	10.2
South East Asian	20487	93	1436	7	21923	3.3
Unknown Other	3,885	94	239	6	4,124	0.6
Maternal education level (years)						
< 12	133698	97	4360	3	138058	21.0
12-15	333616	96	14682	4	348298	52.9
≥16	147685	93	11894	7	159579	24.3
Unknown	8564	95	431	5	8995	1.4
Parity prior to index birth						
0	226616	90	24398	10	251014	38.1
1	206174	98	5250	2	211424	32.1
2	110906	99	1181	1	112087	17.0
3	46523	99	350	1	46873	7.1
4	17356	99	88	1	17444	2.7
5+	14157	100	64	0	14221	2.2
Unknown	4826	97	128	3	4954	0.8
Multiple gestation						
No	622063	95	31300	5	653363	99.3
Yes	4495	97	159	3	4654	0.7
Breech						
No	623773	95	31317	5	655090	99.6
Yes	2785	95	142	5	2927	0.4
Long labor						
No	623541	95	31091	5	654632	99.5
Yes	3017	89	368	11	3385	0.5
Previous cesarean delivery						
No	597771	95	29651	5	627422	95.4

	No (n=626,558)		Yes (n=31,459)		Total	
	N	%	N	%	N	%
Yes	28787	94	1808	6	30595	4.6
Interval between previous and index delivery (years)						
zero-1.5	274152	92	25095	8	299247	45.5
1.5-2.5	94401	98	1495	2	95896	14.6
2.5-4	102561	98	1802	2	104363	15.9
4-6	74435	98	1404	2	75839	11.5
6+	81009	98	1663	2	82672	12.6
induction of labor						
No	532247	95	26252	5	558499	84.9
Yes	94311	95	5207	5	99518	15.1
Occiput-posterior						
No	623254	95	30832	5	654086	99.4
Yes	3304	84	627	16	3931	0.6
Shoulder dystocia						
No	615793	95	29680	5	645473	98.1
Yes	10765	86	1779	14	12544	1.9
Birth weight groups						
< 1000 gms	6575	99	96	1	6671	1.0
1000-1499 gms	1907	100	8	0	1915	0.3
1500-1999 gms	4477	99	49	1	4526	0.7
2000-2499 gms	19801	98	381	2	20182	3.1
2500-2999 gms	97142	97	3015	3	100157	15.2
3000-3999 gms	437847	95	22606	5	460453	70.0
>=4000 gms	58809	92	5304	8	64113	9.7

Procedures for Developing Risk-Adjustment Models

The development of risk-adjustment models followed a series of steps beginning after identification of the outcomes of interest (Cesarean delivery, postpartum readmissions, and perineal lacerations) and potential risk factors. Note that Cesarean delivery is not considered to be a quality-related outcome, but models with this outcome needed to be estimated as part of the readmissions analysis. The steps in developing risk-adjustment models are described in detail below, but may be summarized as follows:

1. Univariate and bivariate analyses were used to identify and eliminate low-frequency risk factors, potential risk factors that were not associated with outcomes and potential risk factors that are associated with counterintuitive outcomes. Similar methods were used to summarize multi-level clinical characteristics as either ordinal predictors or multiple dummy variables.

2. Descriptive analyses were performed to select the best method for modeling the effects of age and other non-clinical risk factors.

3. Each analytic sample (e.g., vaginal delivery patients at risk for perineal laceration, Cesarean delivery patients at risk for postpartum readmission, vaginal delivery patients at risk for postpartum readmission, patients with a history of cesarean delivery at risk for a repeat cesarean) was randomly split into two separate samples for estimating and validating the risk-adjustment models.

4. Clinical risk factors were selected, using the estimation subsample to identify those risk factors with both robust (as defined below) and statistically significant parameter estimates.

5. Statistically significant and clinically meaningful two-way interactions were selected, using variable selection procedures described below.

6. Each risk-adjustment model was internally validated and refined by applying the model developed using the estimation sample to the corresponding validation sample.

7. Each risk model was re-estimated after combining the estimation and validation samples, to generate more reliable parameter estimates.

STEP 1: PRELIMINARY ANALYSES OF CLINICAL RISK FACTORS

These analyses were designed to describe the frequency distributions of all clinical risk factors, detect covariates and covariate patterns with very few observations, evaluate the unadjusted bivariate association between each covariate and the outcomes of interest, and summarize multi-level clinical risk factors in a manner appropriate for regression modeling.

1.1 **The frequency distribution of each clinical risk factor was determined and very low-frequency risk factors were eliminated or aggregated.**

Binary risk factors present in less than 1% of all cases were examined carefully. Whenever possible, these risk factors were combined with physiologically related risk factors that were similarly associated with the outcome of interest. If aggregation along clinical lines was impractical, risk factors present in fewer than 20 patients with that outcome were eliminated.

The following potential risk factors for postpartum readmission were eliminated from the vaginal (V) or cesarean (C) analyses because of low frequency: endometriosis (V,C), peritoneal adhesions (V), placenta previa with or without hemorrhage (V,C), hepatitis (V,C), rheumatic disorders (V,C), renal disease (V,C), abnormal uterus (V), excessive weight gain (V,C), obesity (V), transverse lie (V), thyroid disease (V,C), uterine fibroids (V), seizure disorder (V,C), cardiovascular disease (V,C), mitral valve disorder (V,C), congenital uterine abnormality (V,C), asthma (C), and fetal death (C). Preeclampsia and eclampsia were aggregated into one risk factor that qualified for retention. No potential risk factors for mode of delivery were eliminated because of low frequency.

1.2 **Clinical risk factors not associated with the outcome variable were identified and eliminated, to improve the efficiency of subsequent modeling.**

The unadjusted bivariate association between each clinical risk factor and a binary outcome (e.g., cesarean delivery, readmission) was summarized using relative risk estimates with 95% confidence limits and p values derived from a continuity-adjusted chi-square distribution (with *k-1* degrees of freedom, where *k* equals the number of risk categories). Risk factors that were not associated with the outcome variable at a $p < 0.10$ level were eliminated from further consideration. This cutoff was selected to screen out risk factors least likely to contribute significantly to a multivariate model.

Two potential risk factors were dropped from the analysis of **vaginal** deliveries because they were not significantly related to readmission: excessive fetal growth and premature rupture of membranes. These two risk factors plus abnormal uterus, peritoneal adhesions, uterine fibroids, and multiple gestation were dropped from the analysis of readmissions after **cesarean** delivery for the same reason. No potential risk factors for mode of delivery were eliminated because they were unrelated to the outcome.

1.3 **Clinical risk factors that had counterintuitive associations with the outcome variable were identified and eliminated, if biased coding appeared to be the most likely explanation.**

The directions of all statistically significant associations between risk factors and outcome variables were examined. Risk factors that appeared to lower the risk of postpartum readmission or cesarean delivery, when previous literature and clinical experience suggested the opposite relationship, would have been eliminated from the analysis based on studies demonstrating selective underreporting among patients with poor outcomes.[13,14] However, no potential risk factors for postpartum readmissions or mode of delivery were eliminated for this reason.

1.4 **Multi-level clinical risk factors were summarized as either ordinal predictors or multiple dummy (dichotomous) variables, as appropriate.**

Several clinical risk factors could be divided readily into two or more severity categories, based on the fourth or fifth digit of the ICD-9-CM code or the presence or absence of certain associated diagnoses. For example, diabetes may be classified as complicated if it is associated with ketoacidosis, coma, or end-organ disease (e.g., neuropathy, retinopathy, nephropathy).

[13] Jencks SF, Williams DK, Kay TL. Assessing hospital-associated deaths from discharge data: the role of length of stay and comorbidities. JAMA 1988; 260:2240-2246.

[14] Iezzoni LI, Foley SM, Daley J, Hughes J, Fisher ES, Heeren T. Comorbidities, complications and coding bias: Does the number of diagnosis codes matter in predicting in-hospital mortality? JAMA 1992; 267:2197-2203.

To determine how to model the effect of multi-level clinical risk factors, the unadjusted association between each such factor and a binary outcome (e.g., cesarean delivery, readmission) was summarized using relative risk estimates with 95% confidence limits and p-values derived from a Mantel-Haenszel chi-square for trend. If the relationship between a multi-level predictor and the risk of an adverse outcome was monotonic (and approximately linear on a logit scale), then the predictor was treated as an ordinal variable in regression models. Otherwise, multiple dummy (dichotomous) variables were created to capture the independent effect of each level. Two adjacent levels were combined into one dummy variable if they were associated with the same risk.

The risk factors with multiple levels were diabetes, hypertension, and preeclampsia. All three of these factors demonstrated a linear association with the (logit) risk of readmission and the (logit) risk of cesarean delivery, except that there was no difference between complicated and uncomplicated diabetes in the risk of post-cesarean readmission (so these categories were aggregated).

STEP 2: PRELIMINARY ANALYSES OF NON-CLINICAL RISK FACTORS

These analyses were designed to describe the distributions of all non-clinical risk factors, to evaluate the unadjusted association between each covariate and the outcomes of interest, and to select the appropriate analytic specification of each non-clinical variable.

2.1 **The distribution of age and other continuous predictors, and the associations between these predictors and each outcome of interest, were evaluated.**

Smoothed scatter plots of the logit outcome (log[p/(1-p)]) as a function of **age** were used to determine the best-fitting form of the relationship between that outcome and age. Age was categorized in increments of one to five years, so that each age group had a sufficient number of observations for analysis. Specific components of the age-outcome relationship, such as linear and quadratic terms, were tested using a likelihood ratio statistic. The association between the (logit) risk of postpartum readmission and age was best specified using age and age squared terms, among both vaginal and cesarean deliveries. The association between the (logit) risk of cesarean delivery and age was linear.

The same approach was applied to examine the relationship between the **year and quarter of delivery** (ordered sequentially from the beginning to the end of the study period) and each outcome variable. Because of nonlinear associations, year and quarter of delivery were treated as categorical variables, with the 4^{th} quarter of 1999 as the reference period.

Finally, the **number of antepartum admissions** was evaluated as a risk factor for postpartum readmission. As described in Chapter Four, all hospitalizations occurring within 39 weeks prior to a delivery were ascertained (if a valid social security number was reported). Based on preliminary analyses, the number of antepartum admissions could appropriately be truncated at seven. Truncation was important to minimize the influence of extreme outliers, and to preserve linearity in the association with the logit risk of readmission.

2.2 **The distribution of categorical non-clinical variables and the associations between these variables and each outcome of interest were evaluated.**

Contingency tables were used to evaluate the relationship between each non-clinical categorical risk factor (e.g., race, expected principal source of payment, source of admission, type of admission) and the outcome of interest. This made it possible to combine low-frequency categories that were conceptually similar or had similar outcome rates.

Race was aggregated into seven categories: non-Hispanic white, African-American, Hispanic, American Indian/Native American, Southeast Asian, other Asian,. and other or unknown.

Maternal education was aggregated into four categories: less than or equal to 12 years (high school only), 13-15 years (some college or equivalent), 16 or more years (college graduate), and unknown.

Expected payment source was aggregated into three categories: uninsured, privately insured (including Blue Cross/Blue Shield, insurance company, HMO/PPO, and other non-government), and publicly insured (including MediCal, Medicare, Workers Compensation, Title V, and other government). Expected payment source was tested in the readmission models, but was found not to be a consistent independent predictor in multivariable analyses. It was excluded from the mode of delivery models because it was suspected to be in the same causal pathway as quality of care. In other words, private insurance may increase the risk of cesarean delivery because of an association with poorer obstetric care.

2.3 **One category of each demographic variable was designated as the reference group.**

The most frequent or lowest category of each non-clinical variable was generally chosen as the reference group for regression modeling. In all models, white was the reference category for race. The reference category for maternal education was 12 or fewer years.

STEP 3: DIVISION OF DATA INTO SEPARATE SAMPLES FOR ESTIMATION AND VALIDATION

Each condition-specific data set was split into an estimation sample and a validation sample, by randomly selecting 50% of the original cases (without replacement) for the estimation sample and setting aside the remaining 50% for the validation sample. This procedure made it possible to develop risk-adjustment models on the estimation samples and then assess these models on separate validation samples. Such a test of model fit is more rigorous than one that uses the same sample for both estimation and validation.

STEP 4: SELECTION OF MAIN EFFECTS RISK FACTORS

The goal of Step 4 was to identify a single best set of "main effects" risk factors, incorporating both empirical analysis and evidence from the obstetric literature.

For each subsample, a multivariate logistic regression model was fit using stepwise forward selection with the significance level tolerance set to 0.05, forcing in the important clinical and demographic risk factors identified in Step 1 and 2. Akaike's information criterion (AIC) was also used in variable selection. If AIC increased comparing with the previous step, then the variable was excluded. This procedure was repeated for the validation sample. All risk factors that were selected in both the estimation and validation subsamples were retained.

STEP 5: SELECTION OF RISK FACTOR INTERACTIONS

The number of risk factors was too large to evaluate all possible two-way interactions in multivariate models. The approach adopted in this study reduced the number of candidate interactions to a manageable level and identified the most important interactions for risk-adjustment. The choice of this approach reflects the difficult balance between optimizing model performance and potentially overlifting to the particular set of cases in the development data set.

5.1 **All possible two-way interactions were identified and screened based on two criteria: (1) the number of cases with the adverse outcome, and (2) statistical significance in a stratified analysis. All interactions that passed screening were tested using multivariate methods.**

All possible two-way interactions were identified. A screening procedure was developed to estimate the unadjusted effect of each two-way interaction in a logistic model that included only the main effects involved in that interaction. This simplified logistic model can be expressed as:

$$logit(p_{ij}) = \ln\left(\frac{p_{ij}}{1 - p_{ij}}\right) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \gamma x_1 x_2$$

where $p_{ij} = P(y = 1 \mid x_1 = i, x_2 = j)$. Note that all predictors other than x_1 and x_2 are omitted from this model, and that the values of i and j can be either 0 or 1. To test the null hypothesis that $\tilde{a} = 0$, the following relationship pertains:

$$logit(p_{ij}) = \ln\left(\frac{p_{ij}}{1 - p_{ij}}\right) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \gamma x_1 x_2$$

These logits were estimated from the observed data, by calculating p_{ij} for each risk factor combination (x_1= 1 and x_2= 1, x_1= 0 and x_2= 1, x_1= 1 and x_2= 0, x_1= 0 and x_2= 0, respectively). The variance of *pij* can also be estimated from the observed data (formula available upon request). The 95% confidence interval for p_{ij} is equal to p_{ij} plus or minus 1.96 times the square root of the estimated variance.[15] All interactions for which this confidence interval did not include zero were retained for further testing. In the analysis of mode of delivery, a minimum volume criterion of 20 cases in the lowest frequency interaction category with the less frequent outcome was also applied.

STEP 6: INTERNAL VALIDATION AND REFINEMENT OF RISK ADJUSTMENT MODELS

To internally validate the final covariate set in each risk-adjustment model, the parameter estimates from the 50% estimation sample were compared to the corresponding parameter estimates derived by fitting the same model to the 50% validation sample. Model specification was considered adequate if a parameter estimate from the 50% estimation sample fell within the corresponding 95% confidence intervals from the 50% validation sample.

Nearly all main effects parameter estimates based on the 50% estimation samples were within the corresponding 95% confidence intervals based on the 50% validation samples. Lack of overlap in

[15] In the readmissions analyses, a 90% confidence interval was used (instead of 95%) and the minimum volume criterion was not applied. More lenient screening criteria were appropriate because of the smaller sample size in these analyses.

parameter estimates was noted for a larger number of interaction variables. Some of these variables were statistically significant in the estimation sample, but not in the validation sample. A few even had opposite signs in the two samples (e.g., an adverse effect in the estimation sample and a protective effect in the validation sample). All of these variables were examined individually.

The calibration of each risk-adjustment model was assessed with the Hosmer-Lemeshow goodness of fit test (further described in Chapter Ten). The risk-adjustment model and specific coefficients estimated using the 50% estimation sample were applied to the 50% validation sample. This was important to ascertain whether the model would fit as well in an independent sample as in the sample used for estimation. This comparison generally demonstrated similar goodness-of-fit across risk strata in the two samples, but some calibration problems were identified and addressed.

STEP 7: RE-ESTIMATION OF MODEL PARAMETERS USING ALL CASES

The 50% estimation sample and the 50% validation sample were re-combined into the full dataset. The models were re-estimated by fitting the models developed in Steps 1 through 7 to the complete (100%) data set. The purpose of this step was to generate the most reliable possible estimate of each parameter, using all available data. As described in Step 6, a few variables with questionable clinical significance and inconsistent parameter estimates based on internal validation were dropped at this stage.

The final models re-estimated in this step were used to calculate the predicted probability of cesarean delivery and readmission for each case in the analysis. These predicted probabilities were used in all subsequent analyses of hospital outcomes.

Tables A.20 through A.26 show parameter estimates, odds ratios (ORs), and confidence intervals (CIs) for the risk factors in each of the models.

Table A.20: Odds Ratios for Risk Factors Associated with Readmission- Null Parity Group

Variable	Odds ratio	95% confidence interval	
Maternal education (years)			
≤ 12	Reference		
≥12-15	0.95	0.82	1.10
≥16	0.76	0.63	0.92
Unknown	0.76	0.45	1.27
Maternal race			
Non-Hispanic White	Reference		
Hispanic	0.91	0.81	1.03
African American	1.34	1.14	1.59
American Indian	0.88	0.44	1.78
Other Asian/PI	1.01	0.86	1.19
South East Asian	0.85	0.64	1.14
Unknown/other	0.67	0.31	1.45
Preeclampsia VS/OSHPD			
Yes vs No	1.62	1.41	1.87
Hyptenfnl			
Yes vs No	1.49	1.12	1.98
AmnionitisOSHPfnl			
Yes vs No	1.30	1.06	1.60
Occiput posterior			
Yes vs. No	1.52	1.19	1.94
Number of prior admissions			
N vs n-1	1.29	1.19	1.40
Mode of delivery			
V vs CS	0.49	0.45	0.55

Table A.21: Odds Ratios for Risk Factors Associated with Readmission- Prior Vaginal Delivery Group

Variable	Odds ratio	95% confidence interval	
Maternal education (years)			
≤ 12	Reference		
≥12-15	1.14	0.99	1.30
≥16	0.98	0.81	1.18
Unknown	1.35	0.86	2.11
Maternal race			
Non-Hispanic White	Reference		
Hispanic	0.94	0.83	1.06
African American	1.13	0.94	1.35
American Indian	1.97	1.24	3.13
Other Asian/PI	0.87	0.71	1.07
South East Asian	0.88	0.63	1.21
Unknown/other	0.25	0.08	0.80
Preeclampsia VS/OSHPD			
Yes vs No	1.52	1.24	1.87
Hyptenfnl			
Yes vs No	1.55	1.13	2.13
AmnionitisOSHPfnl			
Yes vs No	1.45	1.01	2.09
Occiput posterior			
Yes vs. No	0.99	0.58	1.69
Number of prior admissions			
N vs n-1	1.48	1.38	1.59
Mode of delivery			
V vs CS	0.45	0.39	0.51
Parity prior to index birth			
1	Reference		
2	1.06	0.93	1.19
3	1.08	0.91	1.28
4	1.48	1.18	1.85
5+	1.37	1.06	1.77
5+	2.11	0.76	5.86

Table A.22: Odds Ratios for Risk Factors Associated with Readmission- Prior C-section Delivery Group

Variable	Odds ratio	95% confidence interval	
Maternal education (years)			
≤ 12	Reference		
≥12-15	0.84	0.69	1.01
≥16	0.76	0.59	0.98
Unknown	1.00	0.53	1.88
Maternal race			
Non-Hispanic White			
Hispanic	0.99	0.82	1.19
African American	1.74	1.38	2.20
American Indian	2.17	1.10	4.28
Other Asian/PI	0.80	0.58	1.10
South East Asian	0.93	0.52	1.66
Unknown/other	1.83	0.82	4.10
Preeclampsia VS/OSHPD			
Yes vs No	1.11	0.83	1.50
Hyptenfnl			
Yes vs No	1.64	1.14	2.37
AmnionitisOSHPfnl			
Yes vs No	1.80	1.18	2.74
Number of prior admissions			
N vs n-1	1.34	1.21	1.49
Mode of delivery			
V vs CS	0.69	0.57	0.83

Table A.23: Adjusted Odds Ratios for Risk Factors Associated with 3rd or 4th Degree Perineal Lacerations at Vaginal Delivery, Excluding Risk Factors Subject to Effect Modification (N=651,643)

Variable	Odds ratio	95% confidence interval	
Maternal education (years)			
≤ 12	Reference		
≥12-15	0.87	0.83	0.90
≥16	0.94	0.90	0.99
Unknown	0.93	0.82	1.05
Maternal race			
Non-Hispanic White	Reference		
Hispanic	0.95	0.92	0.98
African American	0.83	0.78	0.88
American Indian	0.90	0.74	1.09
Other Asian/PI	1.75	1.69	1.82
South East Asian	1.72	1.62	1.82
Unknown/other	1.06	0.90	1.25
Occiput posterior			
Yes vs. No	2.99	2.72	3.28
Breech presentation			
Yes vs No	2.09	1.76	2.48

Table A.24: Results from Multivariate Logistic Regression Models Examining Risk Factors Associated with Perineal Lacerations among Parous and Nulliparous Women who Underwent Vaginal Delivery (Stratified by Age, Parity, Birth Weight, Interval from Last Live Birth to the Index Delivery)*

Parity	0		1		2		3		4		5	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Maternal age (years) ≥35 Versus ≤25	1.3	1.1-1.6	1.5	1.3-1.6	1.9	1.6-2.1	1.6	1.2-1.9	1.4	.9-2.2	1.7	1.0-2.8
Baby's birth weight ≥ 4 000 gms versus ≤ 3000 gms	3.0	2.9-3.1	3.5	3.3-3.7	3.6	3.2-4.0	4.4	3.6-5.4	7.1	4.9-10.6	3.5	2.3-5.4
Cesarean section prior to index delivery Yes versus No			9.4	8.3-10.3	5.6	4.7-6.7	3.4	2.5-4.5	1.9	1.0-3.6	1.5	0.7-3.3
Parity			.12	unable	.04	.04-.05	.03	.02-.03	.02	.01-.02	.02	.01-.03

Model is adjusted at baseline for race, education level, occipitoposterior and breech. Reference group consists of nulliparous women at a mean maternal age of 27.7 years and mean birth weight of 3380 grams.

Table A.25: Results from Multivariate Logistic Regression Models Predicting Risk of Perineal Lacerations and Time Interval between Index and Previous Delivery (Stratified by Previous Cesarean, Maternal Age and Birth Weight)*

Cesarean delivery	Yes		No	
	Odds ratio	95% CI	Odds ratio	95% CI
Time interval between previous and index delivery (years)				
0-1.5 versus 1.5-2.5	1.1	1.0 – 1.3	1.0	.83 – 1.2
2.5-4 versus 1.5-2.5	1.1	1.0 – 1.2	.9	.8 – 1.0
4-6 versus 1.5-2.5	1.3	1.2 – 1.5	.8	.7 – .9

Model is adjusted at baseline for race, education level, occipitoposterior and breech. Reference group consists of parous women at a mean maternal age of 27.7 years, mean birth weight of 3380 grams, and interpregnancy interval of 1.5-2.5 years.

Table A.26: Results from Multivariate Logistic Regression Models Predicting Risk of Perineal Lacerations and Time Interval between Index and Previous Delivery (Stratified by Maternal Age, Birth Weight, Parity) *

Parity	1		2		3		4		5	
	Odds ratios	95% (CI)	Odds ratios	95% (CI)	Odds ratios	95% (CI)	Odds ratios	95% (CI)	Odds ratio	95% (CI)
Time interval between previous and index delivery										
0-1.5 years	1.0	0.9-1.2	0.2	0.2-.25	.08	.06-.12	.02	.01-.05	.02	.01-.05
2.5-4 years	0.9	0.8-1.1	0.2	0.2-.22	.07	.05-0.1	.02	.01-.05	.02	.01-.05
4-6 years	0.7	0.6-0.8	0.1	0.1-0.2	.05	.04-.07	.01	.01-.03	.01	.01-.04
= > 6 Years	0.6	0.5-0.7	0.1	0.1-0.1	.04	.03-.06	.01	.01-.03	.01	.01-.03

Model is adjusted at baseline for race, education level, occipitoposterior and breech. Reference group consists of nulliparous women at a mean maternal age of 27.7 years and mean birth weight of 3380 grams.

Internal Validity of Risk-Adjustment Models

For this report, internal validity is defined as how well the model controls for differences in patient characteristics that would otherwise confound outcome comparisons across hospitals. Not adequately controlling for such differences may generate biased and misleading estimates of risk-adjusted mortality rates. Internal validity was assessed in three ways: face validity, discrimination, and goodness of fit (i.e., calibration).

Face Validity

Members of the Clinical Advisory Panel and additional consultants reviewed the risk-adjustment models, including the selection of covariates and model parameters, to ensure that they were both clinically appropriate and consistent with previous research in the field. This panel judged the models to represent adequately the risk factors associated with postpartum maternal readmissions and perineal lacerations.

Discrimination

A perfectly discriminating model would be able to correctly predict each death. That is, it could assign every patient an expected probability of either zero (survival) or one (death). We do not expect statistical models to be capable of perfect discrimination, but they should be accurate more often than they are wrong (better that 50-50 guessing).

A commonly used measure of discrimination is the C-statistic. This measure is based on comparisons of all possible pairs of cases involving one decedent and one survivor[16]. In the study reported here, the "C-statistic" can be interpreted as the proportion of the times that any randomly selected obstetric patient who experienced an undesired outcome (readmission or laceration) had a higher probability of that outcome than a randomly selected patient who did not experience the outcome. The C-statistic may show a value between 0.00 and 1.00. A value higher than 0.50 indicates an overall pattern of discrimination in the expected direction, where patients who were readmitted or experienced a laceration had higher expected probabilities of the outcome than those were not. A value of exactly 0.50 would indicate random variation, that is, lack of discrimination. Values less than 0.50 would indicate discrimination in an unexpected direction, where patient outcomes were opposite to the predicted outcomes. There is no widely accepted cutoff for the C-statistic that defines a model as "adequate."

As shown in Table A.10, the current models for cesarean delivery have C-statistics between 0.680 (for women with one or more prior cesareans) and 0.858 (for women with prior vaginal deliveries only). The current model for perineal lacerations has a C-statistic of 0.807; whereas the models for postpartum readmissions have somewhat lower C-statistics of 0.603 to 0.628.

[16] The C-statistic is equivalent to the area under a receiver operating characteristic curve, which represents a plot of sensitivity versus 1-specificity at various cutoff values for the predicted probability. See: Hanley JA, McNeil BJ. *The meaning and use of the area under a receiver operating characteristic (ROC) curve*. Radiology 1982; 143:29-36.

Table A.27: Discrimination and Goodness-of-Fit Tests for Risk-Adjustment Models

	Postpartum Readmission			3rd or 4th Degree Perineal Laceration
	Group A (Nullparous)	Group B (prior V only)	Group C (prior CS)	
Number of Cases	334265	408339	118136	651643
Number of readmissions/lacerations	1734	1552	743	31331
Readmission/Laceration rate	0.52%	0.38%	0.63%	4.81%
Degrees of freedom (DF)	19	24	18	63
Discrimination C-statistic	0.628	0.603	0.61	0.807
Hosmer-Lemeshow Goodness of Fit Statistic χ^2	8.938	4.52	9.69	19.97
P-value	0.348	0.807	0.287	0.0104
	Mode of delivery (probability of c-section)			
	Group A(Nullparity)	**Group B (prior V only)**	**Group C (prior CS)**	
Number of Cases	334216	408263	118115	
Number of cesarean deliveries	83912	36750	29826	
Cesarean rate	25.11%	9.00%	25.25%	
Degrees of freedom (DF)	86	97	67	
Discrimination C-statistic	0.799	0.858	0.68	
Hosmer-Lemeshow Goodness of Fit Statistic (χ^2)				
χ^2	158.09	173.09	46.47	
P-value	0.0001	0.0001	0.0001	

Goodness of Fit

Goodness of fit (calibration) is the extent to which observed outcomes correspond to predicted outcomes across the full range of outcome values. In a well-calibrated model, there is a close correspondence between the observed and predicted outcomes across the full range of patient characteristics. A lack of such correspondence (called over-dispersion), can occur for several reasons. There may be a false assumption of a linear relationship between the logit transformation of the dependent variable (i.e., mortality) and its explanatory variables. Alternatively, the model might lack important interaction terms among explanatory variables or might predict extreme values (i.e., outliers) poorly.

Calculation of Hospital Outcome Measures

OBSERVED NUMBER AND RATE OF EVENTS (LACERATIONS OR POSTPARTUM READMISSIONS)

The observed event rate at a hospital equals the observed number of events (perineal lacerations or postpartum readmissions), divided by the total number of qualifying patients at that hospital. This quantity was multiplied by 100 to yield a percentage.

EXPECTED NUMBER AND RATE OF EVENTS (LACERATIONS OR POSTPARTUM READMISSIONS)

The expected number of events at a hospital equals the sum of the probabilities of that event for all of its qualifying patients.

The expected event rate at a hospital equals the expected number of events (perineal lacerations or postpartum readmissions), divided by the total number of qualifying patients at that hospital. This quantity was multiplied by 100 to yield a percentage. The expected event rate can also be viewed as the mean probability of the event across all patients at the same hospital. It is a measure of the average severity of illness at that facility. If the expected event rate at a hospital is higher than the statewide rate, then patients at that hospital tend to be higher risk than the overall population of patients. If the expected event rate at a hospital is lower than the statewide rate, then patients at that hospital tend to be lower risk than the overall population of patients.

Because of the statistical methods used in this study, the number and rate of expected events statewide exactly equal the number and rate of observed events, respectively.

RISK-ADJUSTED POSTPARTUM EVENT (LACERATION OR POSTPARTUM READMISSION) RATE

The risk-adjusted (or indirectly standardized) postpartum event rate at a hospital equals the statewide rate, multiplied by the ratio of the observed number of events to the expected number at that hospital: [17]

$$I_i = S\ (\Sigma_j O_{ij} / \Sigma_j E_{ij})$$

where I_i is the indirectly standardized event rate for the ith hospital, S is the statewide event rate, O_{ij} is the observed value of the adverse outcome (0 or 1) for the jth patient at the ith hospital, and E_{ij} is the expected probability of the event for the jth patient at the ith hospital. The latter two variables are summed over all patients at the ith hospital.

This risk-adjusted event rate provides a basis for comparing the performance of different hospitals, because each hospital's rate is adjusted to reflect what its event rate would be if its patients were about as ill as the statewide average. The ratio of the observed number of events to the expected number at a hospital provides a quick method for assessing a single hospital's performance. For a hospital with fewer observed than expected events, this ratio is less than one; for a hospital with more observed than expected events, this ratio is greater than one.

CONFIDENCE LIMITS FOR RISK-ADJUSTED EVENT (LACERATION OR POSTPARTUM READMISSION) RATES

The 95% confidence limits reflect the level of confidence in a hospital's risk-adjusted event rate. Assuming that the risk model is correct, there is a 95% chance that a hospital's true risk-adjusted event rate falls within these confidence limits. In general, when the upper and lower confidence limits are far apart, the estimated risk-adjusted event rate is unreliable.

[17] Williams RL. Measuring the effectiveness of perinatal medical care. Medical Care 1979; 17:95-110.

These 95% confidence limits were constructed from the standard deviation of the observed number of events at each hospital:

Lower $CI(I_i) = (S/\Sigma_j E_{ij})\ MAX(0, \Sigma_j O_{ij} - 1.96[\Sigma_j (E_{ij})(1 - E_{ij})]^{0.5})$

Upper $CI(I_i) = (S/\Sigma_j E_{ij})\ MIN(n_j, \Sigma_j O_{ij} + 1.96[\Sigma_j (E_{ij})(1 - E_{ij})]^{0.5})$

where I_i, O_{ij}, and E_{ij} are defined as before. The lower confidence limit is constrained so it does not fall below 0%; and likewise the upper confidence limit is constrained not to exceed 100%.

In estimating the standard deviation of the observed number of events, the expected probability of that outcome for each case was treated as a fixed quantity. These probabilities were derived from regression models that included all eligible patients in California. With such large samples, random prediction error is difficult to compute and negligible in comparison with other variance components.[18] The statewide event rate also was treated as a fixed quantity. Therefore, the confidence intervals were constructed around the observed number of events, which was treated as a random variable. Because there is considerable variability within hospitals in patients' probabilities of an event, the variance formula is based on the probabilities for individual patients (which is referred to as the Lexis distribution) rather than the mean probability at a hospital.

EXACT PROBABILITY OF OBSERVED NUMBER OF POSTPARTUM EVENTS (LACERATIONS OR POST-PARTUM READMISSIONS)

The exact probability of the observed number of events (or a more extreme number) occurring by chance, given the expected number of events at a hospital, was used to identify outlier hospitals. This approach differs from the more widely used normal approximation in that it gives better estimates for hospitals with relatively few expected events.[19]

If the observed number of events exceeded the expected number, an upper probability (p) value was computed. If the observed number of events was less than or equal to the expected number, a lower probability (p) value was computed.

The upper p-value for a hospital is the probability that the observed number of events or more occurred by chance. The upper p-value represents a "test" of whether a hospital has systematically worse outcomes than the statewide average. A very small p-value of 0.001 means that one would expect to observe so many events or more only 1 time in 1000, by chance. A more likely explanation for such an extreme finding would be quality of care or some other systematic factor.

The lower p-value for a hospital is the probability that the observed number of events or fewer occurred by chance. The lower p-value represents a "test" of whether a hospital has systematically better outcomes than the statewide average.

[18] Health Care Financing Administration. Medicare Hospital Mortality Information, 1988-1989-1990, Volume 55. Washington, D.C.: US Government Printing Office.

[19] Luft HS, Brown BW Jr. Calculating the probability of rare events: Why settle for an approximation? Health Services Research 1993; 28:419-439.