

An Enhanced Method for Identifying Obstetric Deliveries: Implications for Estimating Maternal Morbidity

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Abstract *Objectives* The accuracy of maternal morbidity estimates from hospital discharge data may be influenced by incomplete identification of deliveries. In maternal/infant health studies, obstetric deliveries are often identified only by the maternal outcome of delivery code (International Classification of Diseases code = V27). We developed an enhanced delivery identification method based on additional delivery-related codes and compared the performance of the enhanced method with the V27 method in identifying estimates of deliveries as well as estimates of maternal morbidity. *Methods* The enhanced and standard V27 methods for identifying deliveries were applied to data from the 1998–2004 Healthcare Cost and

Utilization Project Nationwide Inpatient Sample, an annual nationwide representative survey of U.S. hospitalizations. Odds ratios (ORs) and 95% confidence intervals (CIs) from logistic regression were used to examine predictors of deliveries not identified using the V27 method. *Results* The enhanced method identified 958,868 (3.4%) more deliveries than the 27,128,539 identified using the V27 code alone. Severe complications including major puerperal infections (OR = 3.1, 95% CI 2.8–3.4), hysterectomy (OR = 6.0, 95% CI 5.3–6.8), sepsis (OR = 11.9, 95% CI 10.3–13.6) and respiratory distress syndrome (OR = 16.6, 95% CI 14.4–19.2) were strongly associated with deliveries not identified by the V27 method. Nationwide prevalence rates of severe maternal complications were underestimated with the V27 method compared to the enhanced method, ranging from 9% underestimation for major puerperal infections to 40% underestimation for respiratory distress syndrome. *Conclusion* Deliveries with severe obstetric complications may be more likely to be missed using the V27 code. Researchers should be aware that selecting deliveries from hospital stay records by V27 codes alone may affect the accuracy of their findings.

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Introduction

Epidemiologic studies using hospital discharge data rely on the recording of codes that represent diagnoses and procedures during a hospital stay. In maternal/infant health studies, obstetric deliveries are usually identified by the outcome of delivery code on the maternal discharge record

(International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) code V27) [1]. For example, the V27 code has been used to identify obstetric deliveries in reports based on data from the National Hospital Discharge Survey [2–4]. However, ICD-9-CM codes may be prone to omission from hospital records particularly in cases involving multiple diagnoses and procedures [5]. Investigators have supplemented the V27 code with various other codes in hospital discharge data to identify deliveries, including diagnosis-related group (DRG) codes [6] and ICD-9-CM codes for delivery-related procedures and pregnancy/labor complications [7, 8]. However, the effects of different obstetric delivery identification methods on estimates of maternal morbidity have not been described.

Estimates of maternal mortality based on ICD-9 or ICD-10 codes recorded on death certificates have been shown to be underestimated, because codes for pregnancy/birth are often absent from the death certificates of women who die during childbirth [9–12]. As cases of severe acute maternal morbidity are often clinically similar to cases of maternal death, we hypothesized that deliveries with severe maternal morbidity may lack an indication of delivery based on the V27 code on hospital discharge records. To capture deliveries that may be missed by the V27 code, we developed an enhanced delivery identification method based on additional indications of delivery in hospital discharge records described in previous studies [6–8, 13] and applied this method to data from a large, nationwide representative sample of U.S. inpatient hospitalization records. We tested our hypothesis by examining selected hospital and patient characteristics, obstetric procedures, and pregnancy complications as potential predictors of a delivery not identified using the V27 method, but identified by our enhanced method. We also compared estimated rates of obstetric complications and procedures based on the V27 method with those based on our enhanced method.

Methods

Data

We used data from the Nationwide Inpatient Sample (NIS) of the Healthcare Cost and Utilization Project (HCUP), a federal-state-industry partnership sponsored by the Agency for Healthcare Research and Quality (AHRQ) [14]. During annual data collection all community hospitals from the participating states are stratified by rural/urban location, number of beds, region of the country, teaching status, and ownership. Within each stratum, a systematic random 20% sample of hospitals (total approximately 1,000 hospitals) is drawn [15]. The NIS includes all discharges from the

sampled hospitals and can be used to produce nationwide estimates. Twenty-two states participated in the NIS in 1998, 24 in 1999, 28 in 2000, 33 in 2001, 35 in 2002, and 37 in 2003 and 2004 [16]. The nationwide annual estimates of the total number of discharges from all U.S. hospitals based on estimates from survey data ranged from 34,874,001 in 1998 to 38,661,786 in 2004. This research was determined to be research not involving human subjects and not requiring review by the institutional review board of the Centers for Disease Control and Prevention.

Enhanced Method of Identifying Deliveries

To identify potential obstetric deliveries among all inpatient hospitalization records from 1998 through 2004, we looked for the following information in a hierarchical manner: (1) outcome of delivery (ICD-9-CM disease code = V27), (2) normal delivery (ICD-9-CM disease code = 650), (3) diagnosis-related group (DRG) delivery codes, and 4) ICD-9-CM procedure codes for selected delivery-related procedures. The specific codes that were used in this enhanced method are detailed in Table 1. Hospitalization records were excluded if their discharge summary contained ICD-9-CM codes for abnormal or abortive pregnancy outcomes (Table 1). The elements in the enhanced method were selected on the basis of a record review of all diagnosis and procedure codes conducted by one of the authors (DJ), an obstetrician-gynecologist. Twenty randomly selected records among those identified as potential deliveries by each of the four elements of the enhanced method were reviewed (a total of 80 records). All of these records (100%) were judged to be hospitalizations involving a delivery. In addition to the four elements in the enhanced method, we considered including ICD-9-CM disease codes for pregnancy/labor complications (640.0–648.9 and 651.0–676.9 with a fifth digit of 1 or 2 indicating a delivery) as a last hierarchical element. However, in a review of 20 out of 6,956 randomly selected records identified as potential deliveries using the fifth digit, only 5 (or 25%) were judged to be deliveries. Therefore, this element was not included in the enhanced method.

The DRG classification system is based on a combination of diagnostic and procedure codes along with data on patients' age, sex, and discharge status [17]. Although the DRG classification system is well established, the DRG codes mostly identify deliveries among patients whose primary reason for hospitalization is delivery and may miss those who give birth after having been hospitalized for other reasons. The DRG grouper is applied during the processing of the State Inpatient Databases (SID) and is based on the diagnosis codes (up to 50) and procedure codes (up to 50) that the individual state data collection

Table 1 Elements of the enhanced delivery identification method and the proportion of deliveries identified by each element

Description	Code(s)	Number and percent of total deliveries identified ^a (N = 28,087,407) n (%)
Outcome of delivery	ICD-9-CM = V27	27,128,539 (96.6)
Normal delivery	ICD-9-CM = 650	99,426 (0.35)
Diagnosis-related group (DRG) delivery codes	370 (complicated cesarean section), 371 (uncomplicated cesarean section), 372 (complicated vaginal delivery), 373 (uncomplicated vaginal delivery) 374 (uncomplicated vaginal delivery with sterilization and/or dilatation & curettage) 375 (vaginal delivery with operation room procedure except sterilization and/or dilatation & curettage)	811,191 (3.03)
Selected delivery related procedures	ICD-9-CM = 720, 721, 7221, 7229, 7231, 7239, 724, 726 (forceps) 7251, 7252, 7253, 7254 (breech extraction) 7271, 7279 (vacuum extraction) 728, 729 (other specified and unspecified delivery) 7322 (internal and combined version and extraction) 7359 (other manually assisted deliveries) 736 (episiotomy) 740, 741, 742, 744, 7499 (cesarean section)	5,251 (0.02)
Exclusions	ICD-9 = CM 630 (hydatidiform mole) 631 (other abnormal product of conception) 633 (ectopic pregnancy) 632, 634, 635, 636, 637, 638, 639, 69.01, 69.51, 74.91, 75.0 (abortion)	–

^a Elements were examined in a hierarchical manner in the order listed

partner submits [18]. The number of available diagnosis and procedure codes varies by state in a range of 9 to 30 and 6 to 30 diagnoses and procedure codes, respectively. The NIS file is created after the SID processing for all participating states is complete and truncated at fifteen diagnosis and procedure codes [16]. In addition to DRG codes, we used the ICD-9-CM codes listed above for outcome of delivery, normal delivery, and selected delivery-related procedures as indicators of possible deliveries at any position on the discharge summary since we were interested in identifying all deliveries regardless of the patients' primary reason for hospitalization.

Obstetric Procedures and Complications

We selected obstetric complications to include in our analysis on the basis of complications identified in previous studies [3, 8, 19] and divided the selected conditions into non-severe conditions, severe conditions, and procedures. We defined abnormal forces of labor, long labor, obstructed labor, multiple births, preterm labor, non-severe anesthesia

complication, non-severe postpartum hemorrhage, and diabetes as non-severe complications; and we defined major puerperal infections, severe anesthesia complications, severe postpartum hemorrhage, pulmonary edema, pulmonary embolism, shock, sepsis, acute renal failure, and respiratory distress syndrome as severe complications. We also included in the analysis common obstetric procedures (artificial rupture of membranes, repair of current obstetric lacerations, forceps/vacuum, and cesarean delivery) and procedures which are typically used to treat severe obstetric complications (blood transfusion, hysterectomy, and ventilation). The ICD-9-CM codes for the listed above conditions and procedures are listed in the Appendix.

Statistical Analysis

The unit of analysis was hospitalization not an individual. Our data did not allow us to account for multiple hospitalizations. However, we took care in excluding antenatal and postpartum hospitalizations so that our dataset would include only delivery hospitalizations. In addition,

according to birth certificate data, the probability of delivery twice a year is very low (0.25%) [20]. All results are weighted estimates representing the total number of 1998–2004 delivery hospitalizations in the U.S. We used logistic regression to calculate odds ratios (ORs) and 95% confidence intervals to examine the association between deliveries not identified by the V27 method and selected obstetric complications or procedures. All complications and procedures were coded as yes/no variables except for anesthesia complication and postpartum hemorrhage, which were categorized into three groups: non-severe, severe, and no complication groups. Potential covariates included patient characteristics (year of discharge, maternal age, payer information, number of diagnosis or procedure codes, and length of hospital stay) and hospital characteristics (region (Northwest, Midwest, South, West), location (rural/urban), teaching status (yes/no), and bed size (small, medium, large)). In the final model, we retained only those covariates that were significantly associated with deliveries not identified using the V27 method ($p < 0.05$) after adjustments for other significant covariates. Some states do not report race/ethnicity information to HCUP; the large numbers of discharges without race/ethnicity information (25%) precluded inclusion of this variable in the analysis [18].

We calculated rates of selected obstetric complications and procedures per 1,000 deliveries using both methods for identifying deliveries and examined overestimation or underestimation of rates for specific outcomes based on the V27 method. The magnitude of the bias in rates is reported as the percent difference calculated by dividing the difference in rates by the enhanced method estimated rate and multiplying by 100%.

We used SAS software (version 9.1, SAS Institute Inc. Cary, NC) to manage data and used SAS-callable SURVEY software (version 9.0, RTI International, Research Triangle, NC) to account for the multistage probability sampling design used to collect the data.

Results

The enhanced method initially identified 28,117,941 possible delivery discharges that occurred during 1998–2004. Excluding the 33,536 (0.12%) records with abnormal and abortive pregnancy outcomes (abortions, hydatidiform mole, other abnormal product of conception, or ectopic pregnancy) left 28,084,407 delivery discharges available for analysis. Of these, 27,128,539 deliveries (96.6%) were identified by the V27 method, and 958,868 deliveries (3.4%) were not. Codes for DRG, ICD-9-CM = 650, and selected delivery related procedures identified 811,191; 99,426; and 5,251 of the deliveries not identified by the

V27 method, respectively (Table 1). Less than 0.5 and 0.01% of records had more than 10 diagnosis and procedure ICD-9-CM codes before creation of the state databases, respectively.

Year of delivery as well as patient and hospital characteristics were associated with identification of deliveries using the V27 method (Table 2). Deliveries missed by the V27 method were positively associated with factors that are indirect indicators of risk for severe obstetric complications, such as older age, the presence of fewer than three and more than four diagnoses codes, and longer length of hospital stay.

Deliveries hospitalizations with rare complications were 3–17 times more likely to be missed by the V27 method

Table 2 Associations of deliveries missed by the V27 method with selected patient and hospital characteristics, data from the 1998–2004 Healthcare Cost and Utilization Project Nationwide Inpatient Sample

	N missed = 955,868 (% of total ^a)	Odds ratio ^b	95% confidence interval
<i>Year</i>			
1998	214,805 (5.7)	2.9	1.8, 5.2
1999	148,421 (3.9)	1.9	1.3, 3.1
2000	161,479 (4.0)	1.9	1.1, 3.7
2001	141,138 (3.6)	1.8	1.0, 3.4
2002	106,017 (2.6)	1.3	0.8, 2.2
2003	81,629 (2.1)	1.0	Reference
2004	102,380 (2.4)	1.2	0.6, 2.5
<i>Age, years</i>			
10–19	109,755 (3.5)	1.0	0.9, 1.1
20–34	689,793 (3.3)	1.0	Reference
≥ 35	156,320 (4.0)	1.3	1.2, 1.4
<i>Hospital region</i>			
Northwest	179,566 (3.8)	2.7	1.5, 4.9
Midwest	236,166 (3.9)	3.0	1.9, 4.9
South	448,035 (4.4)	3.4	2.1, 5.7
West	92,102 (1.3)	1.0	Reference
<i>Number of diagnosis codes</i>			
0–2	415,205 (4.9)	2.9	2.6, 3.2
3–4	210,594 (1.9)	1.0	Reference
>4	330,069 (4.1)	2.1	1.8, 2.5
<i>Number of procedure codes</i>			
0–2	414,182 (4.0)	1.2	1.0, 1.5
3–4	286,070 (3.1)	1.0	Reference
>4	255,616 (3.0)	1.0	0.9, 1.1
<i>Length of hospital stay, days^c</i>			
0–1	124,966 (3.0)	1.0	1.0, 1.4
2	400,958 (3.0)	1.0	Reference
≥ 3	429,915 (4.2)	1.5	1.5, 1.6

^a Total deliveries identified by enhanced method

^b Adjusted for all other variables in the table

^c Missing data, N = 3029 (0.3%)

Table 3 Associations of deliveries missed by the V27 method with selected obstetric complications, data from the 1998–2004 Healthcare Cost and Utilization Project Nationwide Inpatient Sample

Complication ^a	N missed = 955,868 (% of total ^b)	Odds ratio ^c	95% Confidence interval
<i>Non-severe complications</i>			
Abnormal forces of labor	98,898 (3.8)	1.14	1.1, 1.2
Long labor	12,551 (4.1)	1.3	1.1, 1.6
Obstructed labor	76,782 (5.0)	1.5	1.4, 1.6
Multiple births	19,334 (4.2)	1.1	1.0, 1.2
Preterm labor	110,850 (5.5)	1.7	1.5, 1.8
Non-severe anesthesia complications ^d	4,475 (5.5)	1.7	1.5, 1.9
Non-severe postpartum hemorrhage ^e	42,725 (5.3)	1.8	1.7, 1.9
Diabetes	66,478 (5.1)	1.6	1.6, 1.7
<i>Severe complications</i>			
Major puerperal infection	17,279 (11.9)	3.1	2.8, 3.4
Severe anesthesia complications ^f	1,050 (13.3)	3.4	2.8, 4.0
Severe postpartum hemorrhage ^g	8,726 (13.3)	4.2	3.7, 4.7
Pulmonary edema	1,344 (22.8)	6.1	5.1, 7.4
Obstetric pulmonary embolism	1,294 (27.5)	9.7	8.1, 11.6
Sepsis	3,134 (35.0)	11.9	10.3, 13.6
Shock	1,376 (37.2)	14.0	11.6, 17.0
Acute renal failure after labor and delivery	2,108 (40.6)	16.0	13.4, 19.1
Adult respiratory distress syndrome	4,708 (42.0)	16.6	14.4, 19.2
Death during hospitalization	875 (36.0)	14.9	11.7, 18.9
<i>Procedures</i>			
Artificial rupture of membranes	144,018 (2.6)	0.8	0.7, 0.9
Repair of current lacerations	8,516,845 (3.0)	1.04	0.9, 1.2
Forceps/vacuum	87,278 (3.6)	1.2	1.1, 1.3
Cesarean delivery	297,617 (4.2)	1.2	1.1, 1.4
Blood transfusion	15,887 (11.9)	3.6	3.2, 4.1
Hysterectomy	4,494 (21.0)	6.0	5.3, 6.8
Ventilation	5,038 (35.0)	13.1	11.4, 15.1

^a Reference group: deliveries without particular conditions and complications

^b Total deliveries identified by enhanced method

^c Adjusted for year, age, number of diagnosis codes, number of procedure codes, length of stay, and hospital region

^d Without involvement of pulmonary, cardiac or central nervous systems

^e Not requiring hysterectomy, blood transfusion or both

^f With involvement of pulmonary, cardiac or central nervous systems

^g Requiring hysterectomy, blood transfusion or both

compared to deliveries hospitalizations without these complications. The magnitude of the associations increased with the severity of complications (Table 3): for major puerperal infections, for pulmonary edema, and for adult respiratory distress syndrome the odds ratios were 3.1 (95% CI: 2.8, 3.4), 6.1 (95% CI: 5.1, 7.4), and 16.6 (95% CI: 14.4, 19.2), respectively. Deliveries of women with artificial rupture of membranes (OR = 0.8, 95% CI: 0.7, 0.9) were less likely to be missed by the V27 method than deliveries of women without this procedure. Deliveries by women who had blood transfusions, hysterectomy, or ventilation were 3.6 (95% CI: 3.2, 4.1), 6.0 (95% CI: 5.3,

6.8) and 13.1 (95% CI: 11.4, 15.1) times more likely to have been missed by the V27 method than were deliveries by women who did not have these procedures. To confirm the severity of cases included in our analysis, we also examined in-hospital case-mortality rates. The highest mortality rates were observed among delivery hospitalizations that were complicated by ventilation (10.3%), pulmonary embolism (8.7%), respiratory distress syndrome (6.1%), shock (6.0%), acute renal failure (5.1%), sepsis (3.0%), and hysterectomy (1.0%). These conditions were also among the strongest predictors of deliveries being missed by the V27 method.

The choice of delivery identification method had little effect on estimates of the rates of common obstetric procedures (less than 1%). However, when compared to the enhanced method, the V27 method underestimated the rates of hysterectomy and ventilation by 18.4 and by 31.4%, respectively. The choice of method for delivery identification also had a substantial impact on estimates of the rates of severe obstetric complications. Compared to the enhanced method, the V27 method underestimated rates of minor complications by 0.4–2.1% but underestimated rates of major complications by 8.9–40.0% (Table 4). Complications most likely to be missed by V27 method included: pulmonary edema, pulmonary embolism, shock, sepsis, renal failure and respiratory distress syndrome. Thus, the underestimation was especially pronounced for the most extensive obstetric complications.

Discussion

To our knowledge, our study is the first to investigate the effects of different obstetric delivery identification methods on maternal morbidity statistics. Most studies of maternal health outcomes using hospital discharge data use the ICD-9-CM code V27 to identify deliveries [2–4]. Using our enhanced method incorporating three additional sources of information, we were able to identify an additional 958,868 deliveries over the 7-year-time period. Importantly, these deliveries were not representative deliveries identified using the V27 code. Deliveries with severe obstetric complications were 3–17 times more likely to be missed by the V27 method. Reports based on the V27 method underestimated the rates of severe obstetric complications by 9–40%. We suspect that because severe maternal complications are serious events, those responsible for assigning ICD-9-CM codes may be distracted from their routine task of assigning V27 delivery codes by the need to report the appropriate ICD-9-CM codes related to the complications and by the need to assign more codes than they would need to do for uncomplicated cases. In support of this assertion, we found that the V27 method missed less than 5% of deliveries involving non-severe complications and an even lower percentage of deliveries involving common obstetric procedures. Although it is also possible that the V27 code was truncated on some hospital discharge records during creation of state or the HCUP databases, a very small percent of records had more than 10 ICD-9-CM diagnosis or procedure codes originally.

During the last 25 years, maternal mortality statistics have been based on ICD-9 or ICD-10 codes obtained from death certificates [21]. In a recent study of maternal mortality statistics from US regions and Europe, researchers reported that estimates of maternal death rates based on

death certificate data alone were substantially lower than those based on an enhanced maternal death identification method, with the difference ranging from 22% in France to 93% in Massachusetts [9]. Maternal deaths missed by the use of ICD-9 or ICD-10 codes on death certificates are often identified by incorporating information from other sources, such as any mention of pregnancy, birth, or puerperium on the death certificate during manual review or by a computer-based linkage of death certificates with birth registries. A national record linkage of death and birth registries and the addition of a question about decedents' pregnancy status on death certificates have been recommended as ways of improving the ascertainment of maternal deaths [12]. In our study, we investigated a similar problem related to maternal morbidity. Since maternal deaths have become extremely rare events in industrialized countries, maternal morbidity has increasingly replaced maternal mortality as the primary indicator of the quality of obstetrical care [22].

The results of our study should be interpreted in light of at least two limitations. First, although our enhanced method was based on additional sources of information that have been used previously to compliment the V27 code [6–8, 13], we were not able to validate our enhanced method by examining medical records. However, our estimate of the number of U.S. deliveries from 1998 through 2004 based on the enhanced method (28,084,407) was similar to the number estimated by the National Center for Health Statistics (NCHS) on the basis of birth certificates (28,231,180) [23]. Another limitation of our study relates to our reliance on ICD-9-CM codes to estimate rates of obstetric complications. For some obstetric complications ICD-9-CM codes may have low sensitivity, low positive predictive values or have not been validated in hospital discharge data. We did not examine some complications (venous thromboembolism, uterine rupture, and preeclampsia/eclampsia) for which the positive predictive values of ICD-9-CM codes are low, ranging from 39 to 54% [24–26]. Our estimated rates for some other complications, such as major puerperal infection and postpartum hemorrhage, may be underestimated even by the enhanced method due to the low sensitivity of ICD-9-CM codes for these conditions [8, 19]. Future studies are needed to investigate the validity of ICD-9-CM codes for rare obstetric complications in hospital discharge data.

Our findings have two practical implications. First, they indicate that prevalence estimates of maternal morbidity, particularly severe conditions, from hospital discharge data may be underestimated when deliveries are captured using only the V27 code. Second, prevalence rates have not previously been published for many rare obstetric complications. Our study not only reports nationwide prevalence estimates for rare obstetric complications, but

Table 4 A comparison of the rates of selected obstetric complications estimated by the V27 method with those estimated by the enhanced method, data from the 1998–2004 Healthcare Cost and Utilization Project Nationwide Inpatient Sample

Obstetric complications	V27 method (N = 27,128,539)		Enhanced method (N = 28,084,407)		Under (-)/overestimation (+) by V27 method ^a
	N	Rates (SE) ^b	N	Rates (SE) ^b	
<i>Non-severe complications</i>					
Abnormal forces of labor	2,524,444	93.06 (0.89)	2,623,342	93.41 (0.87)	-0.4
Long labor	291,678	10.75 (0.34)	304,230	10.83 (0.34)	-0.7
Obstructed labor	1,469,616	54.17 (0.63)	1,546,397	55.06 (0.65)	-1.6
Multiple births	445,166	16.41 (0.16)	464,500	16.54 (0.16)	-0.8
Preterm labor	1,915,679	70.62 (0.62)	2,026,528	72.16 (0.64)	-2.1
Non-severe anesthesia complications ^c	76,343	2.81 (0.05)	80,818	2.87 (0.05)	-2.1
Non-severe postpartum hemorrhage ^d	757,547	27.92 (0.31)	800,272	28.50 (0.32)	-2.0
Diabetes	1,231,705	45.40 (0.40)	1,298,183	46.22 (0.40)	-1.8
<i>Severe complications</i>					
Major puerperal infection	128,369	4.73 (0.15)	145,649	5.19 (0.16)	-8.9
Severe anesthesia complications ^e	6,872	0.255 (0.009)	7,922	0.282 (0.010)	-9.6
Severe postpartum hemorrhage ^f	56,755	2.09 (0.04)	65,481	2.33 (0.04)	-10.3
Pulmonary edema	4,545	0.168 (0.008)	5,889	0.210 (0.010)	-20.6
Obstetric pulmonary embolism	3,412	0.126 (0.006)	4,706	0.166 (0.007)	-24.1
Sepsis	5,829	0.215 (0.008)	8,963	0.319 (0.010)	-32.6
Shock	2,326	0.086 (0.004)	3,703	0.132 (0.005)	-34.9
Acute renal failure after labor and delivery	3,080	0.114 (0.005)	5,189	0.185 (0.007)	-38.4
Adult respiratory distress syndrome	6,512	0.240 (0.007)	11,220	0.400 (0.010)	-40.0
Death during hospitalization	1,387	0.057 (0.004)	2,157	0.087 (0.004)	-34.5
<i>Procedures</i>					
Artificial rupture of membranes	5,611,790	201.55 (3.54)	5,467,772	199.82 (3.50)	+0.9
Repair of current lacerations	8,546,845	313.94 (1.74)	8,776,276	312.496 (1.71)	+0.5
Forceps/vacuum	2,329,043	85.25 (0.84)	2,416,321	86.04 (0.84)	-0.9
Cesarean delivery	6,810,705	251.05 (1.20)	7,108,322	253.11 (1.20)	-0.8
Blood transfusion	117,499	4.33 (0.09)	133,385	4.75 (0.10)	-8.8
Hysterectomy	16,915	0.62 (0.01)	21,409	0.76 (0.01)	-18.4
Ventilation	9,375	0.35 (0.01)	14,413	0.51 (0.01)	-31.4

^a Underestimation/overestimation of rates was calculated as the difference between V27 rates (among identified by V27 method) and enhanced rates (among identified by enhanced method) divided by the enhanced rate and multiplied by 100%

^b Per 1,000 deliveries; SE-standard error

^c Without involvement of pulmonary, cardiac or central nervous systems

^d Not requiring hysterectomy, blood transfusion or both

^e With involvement of pulmonary, cardiac or central nervous systems

^f Requiring hysterectomy, blood transfusion or both

may also provide more accurate estimates through a more complete ascertainment of deliveries.

In summary, our results suggest that relying solely on V27 codes in hospital discharge data to identify deliveries could lead to underestimates of the prevalence of severe obstetric complications and that an enhanced delivery identification method may yield more accurate results. Researchers should be aware that the method they use to identify deliveries in hospital discharge data may affect the accuracy of their findings.

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Appendix

Complications	ICD-9-CM codes
Abnormal forces of labor	660
Long labor	661
Obstructed labor	662
Multiple births	651, V27.2, V27.3, V27.4, V27.5, V27.6, V27.7
Preterm labor	644.2
Non-severe anesthesia complications	668.8, 668.9
Non-severe postpartum hemorrhage/hematoma	666, 674.3
Diabetes	250.00–250.33, 250.40–250.93, 648.0, 648.8
Major puerperal infection	670, 672
Severe anesthesia complications	668.0, 668.1, 668.2, 995.4
Severe postpartum hemorrhage/hematoma	Codes for non-severe postpartum hemorrhage¶ + codes for blood transfusion and/or hysterectomy
Pulmonary edema	518.4, 428.1
Obstetric pulmonary embolism	673
Sepsis	038.0–038.9, 785.52, 785.59, 995.91, 995.92
Shock	669.1, 998.0
Acute renal failure after labor and delivery	669.3
Adult respiratory distress syndrome	518.5, 518.81, 518.82
Artificial rupture of membranes	73.0x
Repair of current lacerations	75.5x–75.6x
Forceps/vacuum	72.0–72.9, 73.3
Cesarean delivery	74.0, 74.1, 74.2, 74.4, 74.9x
Blood transfusion	99.00–99.09
Hysterectomy	68.3–68.9
Ventilation	93.90, 96.01–96.05, 96.7x

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