Hospital Variations in Unexpected Complications Among Term Newborns

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abstract

OBJECTIVES: To examine contributing factors and potential reasons for hospital differences in unexpected newborn complication rates in Florida.

METHODS: We conducted a population-based retrospective cohort study of linked birth certificate and hospital discharge records from 2004 to 2013. The study population included 1 604 774 term, singleton live births in 124 hospitals. Severe and moderate complications were identified via a published algorithm. Logistic mixed-effects models were used to examine risk factors for complications and to estimate the percentage of hospital variation explained by factors. Descriptive analyses were performed to explore reasons for the differences.

RESULTS: Hospital total complication rates varied from 6.7 to 98.6 per 1000 births. No correlation between severe and moderate complication rates by hospital was identified. Leading risk factors for complications included medically indicated early-term delivery, no prenatal care, nulliparity, prepregnancy obesity, tobacco use, and delivery in southern Florida hospitals. Hospital factors such as geographic location, level of care or birth volume, and Medicaid births percentage explained 35% and 27.8% of variation in severe and moderate complication rates, respectively. Individual factors explained an additional 6% of variation in severe complication rates. Different complication subcategories (eg, infections, hospital transfers) drove the hospital factors that contributed to severe and moderate complications.

CONCLUSIONS: Variation in unexpected complication rates is more likely to be related to hospital rather than patient characteristics in Florida. The high proportion of variation explained by hospital factors suggests potential opportunities for improvement, and identifying specific complication categories may provide focus areas. Some of the opportunities may be related to differences in hospital coding practice.

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WHAT'S KNOWN ON THIS SUBJECT: Unexpected complication rates among low-risk term newborns vary widely by hospital. The National Quality Forum–endorsed unexpected newborn complications measure may help identify opportunities to reduce variability in complication rates and improve outcomes among term infants.

WHAT THIS STUDY ADDS: To date, no studies have examined drivers of hospital variation in unexpected complication rates. We quantified the contribution of individual and hospital factors to hospital variation in unexpected complication rates and explored potential reasons for the differences in Florida.

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To date, research on perinatal care and the risk of adverse neonatal outcomes has focused frequently on the roles played by prematurity and care processes, such as induction and cesarean delivery.[1–3] Among the 5 core perinatal quality measures recommended by The Joint Commission, 1 focuses on elective inductions and cesareans among early-term deliveries and another on cesarean deliveries in first-time mothers at term.[4] These measures have enabled standardized tracking of adverse neonatal outcomes, which continue to occur among low-risk pregnancies at nontrivial rates.[5] However, uncertainties remain about the extent to which improved hospital performance in these care processes results in better neonatal outcomes.[6,7] The opportunities to improve care for term newborns, the largest population of births, remain underexplored.

In response to the need for a quality measure that focuses on outcomes in term infants, the California Maternal Quality Care Collaborative (CMQCC) developed the unexpected newborn complications measure.[8] With National Quality Forum endorsement of the measure, descriptive analyses in California and the US East Coast showed substantial variation in hospital rates of unexpected complications.[9] Although this information suggests opportunities for improvement, no studies have examined risk factors for unexpected complications, quantified their contribution to hospital rate differences, or explored reasons for the variation. We investigated individual and hospital factors associated with unexpected complications, assessed the extent to which they explain hospital variation in complications, and explored potential causes for the differences in Florida. Findings may have implications for the use of this measure as a benchmark in reducing variability in unexpected newborn complications.

METHODS

We conducted a population-based retrospective cohort study by using Florida's linked birth certificate and maternal–infant inpatient hospital discharge records from 2004 to 2013. More than 92% of Florida resident births are generally captured in the linkage. Births to mothers who are foreign born, unmarried, with lower education levels are least likely to be captured.[10] Our group has previously compared the accuracy of linked data to birth certificate or hospital discharge alone.[11] Data use agreements were completed with the Florida Department of Health and the Agency for Health Care Administration (AHCA). This study was part of the Perinatal Quality Improvement project, approved by the Florida Department of Health and University of South Florida institutional review boards.

Data for this study were limited to delivery admissions in nonmilitary hospitals. The eligible population consisted of term (37–41 completed weeks), singleton nonanomalous live births weighing ≥2500 g, without preexisting fetal or placental conditions or exposure to maternal drug use. These infants are generally expected to do well and go home routinely with the mother.[12] To focus on routine delivery hospitals, we included only births from hospitals with >100 annual births (124 hospitals). Records with birth weight >8125 g (ie, potentially implausible) and records without maternal age, race and ethnicity, or education level information were excluded. Exclusions made up <1% of eligible births.

Unexpected complications were measured according to the CMQCC algorithm, with discharge codes, length of stay (LOS), and Apgar scores from the birth certificate.[12] Case definitions and study variable descriptions are provided in Table 1. We first identified severe complications, consisting of neonatal deaths, neonatal hospital transfers, extremely low Apgar score at 5 or 10 minutes of life, severe birth injuries, respiratory problems, infections, and neurologic complications. We then identified moderate complications, consisting of less severe respiratory problems, infections with a longer LOS but not sepsis, less severe neurologic complications, and unspecified long LOS without jaundice or social reasons.[12] Combined, severe and moderate complications made up the number of total complications in the study population. In this hierarchical, mutually exclusive classification, births with both severe and moderate complications counted only toward the number of severe complications. One difference from the CMQCC algorithm is our inability to verify that hospital transfers were transfers to a higher neonatal level of care. With the current available data, we are unable to determine the receiving hospital's level of care. However, transfer frequency decreased substantially with increasing level.

Individual and hospital factors were selected for analysis based on the literature and clinical significance. The following socioeconomic factors were included in the final analysis: maternal age, race and ethnicity from the birth certificate, education level, marital status, father's acknowledgment, and insurance status. Medical factors consisted of birth order and history of cesarean delivery, prepregnancy BMI, and self-reported tobacco use during pregnancy. Individual health service factors consisted of adequacy of prenatal care, timing and reason for delivery initiation, and delivery day of the week. We used information from The Joint Commission[4] to classify timing and reason for delivery initiation in

the following 6 mutually exclusive groups: spontaneous labor at 37 to 38 weeks, medically indicated induction or cesarean without labor at 37 to 38 weeks, non–medically indicated (NMI) induction at 37 to 38 weeks, NMI cesarean without labor at 37 to 38 weeks, ≥39 weeks' delivery with medical indication for early delivery, and ≥39 weeks' delivery without medical indication for early delivery.[13] Presence or absence of labor was determined from information from the birth certificate and hospital discharge (Table 1). The following hospital health service factors were included in the final analysis: annual birth volume in quartiles by neonatal care level, based on current Florida licensure (AHCA: I–III), annual percentage of births to Medicaid patients (quartiles), and geographic location.

Data Analysis

Frequencies were used to describe complication rates in the study population. Complications were modeled as a function of study factors via logistic mixed-effects regression.[14] For all models, a random hospital intercept was specified to compare the between-hospital variation in complication rates before and after risk adjustment. Factors selected a priori, based on the literature and clinical significance, were first assessed individually in univariable models for total complications. Significant risk factors ($P < .05$) identified in this step were selected for inclusion in a multivariable model, adjusted for multiple factors at a time. Factors were added in groups as follows: (1) individual socioeconomic and medical factors, (2) individual health service factors, (3) hospital health service factors, and (4) year of birth. At each step, the model retained only factors significantly associated with total complications at the .05 level. Year of birth was retained in the final model (4) to account for time-varying hospital factors (eg, annual birth volume). Because there were minimal changes to adjusted odds ratio (aOR) estimates between models 2, 3, and 4, we report only aORs from the univariable models and the final model (4). To examine differences in risk factors by type of complication, we reran the final model separately for severe and

TABLE 1 Study Population, Outcomes, and Factors for the Study of Hospital Differences in Unexpected Newborn Complications (Florida, 2004–2013)

	Source
Study population[a]	
Inclusion criteria	
Singleton	HD, BC
Term (37–41 completed wk gestation)	BC
Birth wt ≥2500 g	BC
Exclusion criteria	
Congenital anomalies (ICD-9 diagnosis codes)	HD
Maternal drug use (ICD-9 diagnosis codes)	HD
Fetal and placental conditions (diagnosis codes): placenta previa affecting fetus or newborn, light for dates, fetal growth retardation, hemolytic disease, hydrops fetalis	HD
Unexpected newborn complications[a]	
Severe	
Neonatal death	BC
Neonatal transfer to another hospital	HD, BC
Apgar score ≤3 at 5 or 10 min	BC
Severe ICD-9 diagnosis and procedure codes: birth trauma, hypoxia asphyxia, shock and resuscitation, respiratory (eg, continuous positive airway pressure use), infection (eg, severe sepsis), neurologic (eg, intraventricular hemorrhage)	HD
Sepsis and neonatal LOS >4 d	HD, BC
Moderate	
Moderate ICD-9 diagnoses and procedures: birth trauma, respiratory (eg, transient tachypnea of the newborn)	HD
Moderate ICD-9 diagnoses and procedures with neonatal LOS >4 d for cesarean delivery or neonatal LOS >2 d for vaginal delivery: birth trauma, respiratory, neurologic (eg, tomography of head), infection	HD, BC
Long neonatal LOS: LOS >5 d without jaundice or social code	HD, BC
Unexpected newborn complication subcategories	
Respiratory: severe and moderate ICD-9, moderate ICD-9 with LOS requirement as above	HD, BC
Infection: severe ICD-9 and moderate ICD-9 with LOS requirement as above	HD, BC
Transfer to higher level of care: used transfer to another hospital as proxy	HD, BC
Neurologic or birth injury: severe and moderate ICD-9, moderate ICD-9 with LOS requirement as above	HD, BC
Shock and resuscitation: severe ICD-9	HD
Long neonatal LOS (unspecified): long LOS as above	HD, BC
Individual socioeconomic factors	
Maternal age, y: <20, 20–29, 30–39, ≥40	BC
Maternal race and ethnicity: NH white, NH black, Mexican, Puerto Rican, Cuban, Central or South American, other	BC
Hispanic, Haitian, other NH	
Nativity: Florida born, US born non-Florida, foreign born	BC
Marital status: married, not married	BC
Father acknowledgment: father's age reported on birth certificate	
Maternal education: less than high school, high school or GED, some college (no degree), college graduate	BC
Insurance status: Medicaid, private, self-pay, other	HD
Individual medical risk factors	
Birth order and reproductive history: first, second, or third without previous cesarean, second or third with previous cesarean, fourth or later without previous cesarean, fourth or later with previous cesarean	HD, BC
Prepregnancy BMI: underweight (<18.5), normal (18.5–24.9), overweight (25–29.9), obese I (30–34.9), obese II (35–39.9), obese III (≥40)	BC
Maternal tobacco use during pregnancy: yes, no	HD, BC
Individual-level health service factors	
Adequacy of prenatal care (GINDEX): intensive/adequate, intermediate, inadequate, no care	BC

TABLE 1 Continued

	Source
Timing and reason for delivery initiation[b]	HD, BC
Spontaneous labor at 37–38 wk: vaginal birth without a record of induction (hospital discharge or birth certificate), cesarean without a record of induction but with either trial of labor or labor augmentation (birth certificate)	
Medically indicated induction or cesarean at 37–38 wk[b]	
NMI induction at 37–38 wk	
NMI cesarean without labor at 37–38 wk: cesarean without labor induction (hospital discharge or birth certificate), without trial of labor or augmentation reported (birth certificate), and without a medical indication for early delivery	
Delivery at ≥39 wk with medical indication for early delivery[b]	
Delivery at ≥39 wk without medical indication for early delivery	
Delivery day of week: weekday (Monday–Friday), weekend (Saturday–Sunday)	BC
Hospital-level health service factors	
Hospital level of NICU (I–III) and hospital annual birth volume (quartiles by level of NICU)	AHCA, BC
Hospital percentage of Medicaid births (quartiles by year)	HD
Hospital percentage of certified nurse midwife births (quartiles by year)	BC
Hospital rural or urban location (NCHS): large central metro; large fringe metro; medium metro; small, micro, nonmetro	BC
Hospital ownership: not-for-profit, investor owned, local government owned	AHCA
Hospital geographic location, based on ACOG District XII (Florida) map: Northwestern (Section 1: Panhandle)	BC
Northeastern (Section 2: Northern), Central (Section 3), Western (Section 4), Eastern (Section 5), Southern (Section 6: Peninsula)[c]	
Hospital percentage of inductions: quartiles by year	HD, BC
Hospital percentage of cesarean deliveries: quartiles by year	HD, BC
Hospital percentage of nulliparous, term, singleton, vertex cesarean deliveries (quartiles by year)	HD, BC
Hospital obstetric and pediatric residency programs	ACGME
Year of delivery: 2004–2013	BC

ACGME, Accreditation Council for Graduate Medical Education; ACOG, American Congress of Obstetricians and Gynecologists; BC, birth certificate; GINDEX, Graduated Index of Prenatal Care Utilization; HD, hospital discharge; ICD-9, International Classification of Diseases, Ninth Revision; NCHS, National Center for Health Statistics; NH, non-Hispanic.

[a] Study population inclusion and exclusion criteria and study outcomes are standard definitions for the unexpected newborn complications measure, as proposed by the CMQCC (https://www.cmqcc.org/resources/2952/download).

[b] List of medical indications provided in Supplemental Table 5, The Joint Commission's *List of Conditions Possibly Justifying Elective Delivery*, v2015A1. Adapted from Table 11.07, available at: https://manual.jointcommission.org/releases/TJC2015A1.

[c] ACOG District XII (Florida) map available at: http://www.acog.org/About-ACOG/ACOG-Districts/District-XII.

moderate complications. The model for severe complications excluded infants with moderate complications and vice versa. We estimated the variation explained by study factors by calculating the reduction, if any, in between-hospital variance from unadjusted to adjusted models (Supplemental Fig 2). To estimate the consistency of complication rates by hospital over time, we calculated the intraclass correlation coefficient from linear mixed-effects models of hospital complication rates by year. To explore potential reasons for hospital differences, we assessed frequencies of complication diagnosis subcategories (respiratory, infectious, hospital transfer, neurologic or birth injury, shock and resuscitation, unspecified long LOS, and neonatal death).[15] Analyses were conducted in SAS software (SAS Institute, Inc, Cary, NC).

RESULTS

Among 1 604 774 births in the study population, 28 853 (1.8%) had severe complications and 30 033 (1.9%) had moderate complications. The total complication rate was 37 per 1000 (3.7%). Unadjusted total complication rates varied by socioeconomic, medical (Table 2), and health service factors (Table 3). The highest rates among individual and hospital factors were observed for no prenatal care (70.6 per 1000) and delivery in high–Medicaid percentage hospitals (48.6 per 1000), respectively (Table 3). Hospital-specific rates of total complications varied 14-fold, from 6.7 to 98.6 per 1000 (Fig 1). There was no correlation between severe and moderate rates by hospital (r = 0.04). Hospital complication rates were moderately consistent over 10 years (intraclass correlation coefficient 0.65 for severe and 0.67 for moderate).

After risk adjustment, the leading individual factors in the final multivariable model were health services, followed by medical and then socioeconomic factors (Table 4). Medically indicated induction or cesarean at 37 to 38 weeks was associated with twice or greater odds of severe (aOR 2.3; 95% confidence interval [CI], 2.2–2.4) and moderate complications (aOR 1.98; 95% CI, 1.9–2.1). Additional moderate to strong factors for severe complications included delivery at ≥39 weeks with medical indication, no prenatal care, spontaneous delivery at 37 to 38 weeks, NMI cesarean at 37 to 38 weeks, nulliparity, and extreme prepregnancy obesity (aORs ranging from 1.5 to 1.8). Moderate to strong factors for moderate complications included no prenatal care, spontaneous delivery at 37 to 38 weeks, delivery at ≥39 weeks with medical indication, and tobacco use (aORs ranging from 1.4 to 1.8). Additionally, NMI induction at 37 to 38 weeks increased the odds of both severe and moderate complications by 1.2 times (95% CI, 1.1–1.3). Adjusting for significant individual factors reduced the observed hospital variation in severe complications by 6% but did not reduce hospital variation in moderate complications (Supplemental Fig 2). Among hospital factors, higher odds of severe complications were associated with births in southern Florida hospitals (aOR 1.9; 95% CI,

1.5–2.5), smaller, level I hospitals (aOR 1.6; 95% CI, 1.3–1.9), and high–Medicaid percentage hospitals (aOR 1.4; 95% CI, 1.3–1.6). Level of care and birth volume was the only significant hospital factor for moderate complications (aOR for smaller, level I hospitals 0.7; 95% CI, 0.6–0.9). Adding hospital geographic location, level of care and birth volume, and Medicaid births percentage to the model containing significant individual factors reduced the hospital variation in severe and moderate complication rates by an additional 35% and 27.8%, respectively. Adjusting for delivery year reduced an additional 4.1% of hospital variation in severe complications (Supplemental Fig 2). The odds of severe complications were 1.2 times greater in the last 4 years of the study period (95% CI, 1.1–1.2) (Table 4).

The distribution of complication and diagnosis categories by hospital factors is summarized in Supplemental Table 6. Based on observed rates, variables for level of care or birth volume and geographic location were simplified to 3 levels. The most common category for severe complications was infection, followed by neonatal transfer. The most common category for moderate complications was respiratory, followed by unspecified long neonatal LOS. Most categories had prevalence trends that were consistent with significant hospital factors. The highest rates of severe infections were observed among births in southern Florida hospitals (18.9 per 1000) and high–Medicaid percentage hospitals (11 per 1000). Neonatal transfers, 95% of which occurred in the first 4 days of life, were most prevalent among births in level I hospitals (14.8 per 1000) and high–Medicaid percentage hospitals (9.9 per 1000). Conversely, the highest rates of moderate respiratory issues and unspecified long LOS were observed among births in level III hospitals (19.7 and 4.7 per 1000, respectively) (Supplemental Table 6). Of note, high percentages of Medicaid births clustered predominantly in level III (44%) and level I hospitals (36%). Hospital-specific transfer rates ranged from 0 to 67 per 1000 in level I hospitals and from 0 to 3 per 1000 in level III hospitals. Hospital-specific rates of moderate respiratory issues ranged from 8 to

TABLE 2 Unexpected Complication Rates by Individual Socioeconomic and Medical Factors (Florida, 2004–2013)

		Term Births	Unexpected Complication Rate (per 1000 Live Births)		
			Total	Severe	Moderate
Total		1 604 774	36.7	18.0	18.7
Socioeconomic					
Maternal age, y	<20	149 166	44.2	22.6	21.6
	20–29	854 671	37.8	18.6	19.2
	30–39	556 901	33.2	15.9	17.3
	≥40	44 036	36.3	17.7	18.6
Maternal race and ethnicity	NH white	762 011	37.2	17.5	19.7
	NH black	284 460	38.6	19.8	18.8
	Hispanic: Mexican	89 740	33.9	16.4	17.5
	Hispanic: Puerto Rican	87 806	31.6	15.4	16.2
	Hispanic: Cuban	88 238	38.0	23.5	14.5
	Hispanic: Central or South American	98 086	34.8	16.7	18.1
	Other Hispanic	65 269	34.8	17.3	17.5
	Haitian	53 423	44.7	20.6	24.1
	Other, NH	75 741	30.7	14.9	15.8
Maternal marital status	Married	887 336	31.6	15.3	16.3
	Not married	717 438	43.0	21.3	21.7
Father acknowledged on BC[a]	Yes	1 427 969	35.2	17.2	18.0
	No	176 805	48.6	24.0	24.6
Maternal education	Less than high school	267 733	44.2	21.4	22.8
	High school graduate or GED	507 320	40.9	20.6	20.3
	Some college (no degree)	302 707	36.2	17.5	18.7
	College graduate (associate or greater)	527 014	29.2	14.0	15.2
Insurance status	Medicaid	790 754	43.0	21.4	21.6
	Private	734 792	29.7	14.3	15.4
	Self-pay	60 742	34.3	16.5	17.8
	Other	18 486	52.4	22.4	30.0
Medical					
Birth order and history	First delivery	676 167	43.5	22.3	21.2
	Second or third, without previous CS	542 965	31.4	14.0	17.4
	Second or third, with previous CS	229 591	28.4	14.8	13.6
	Fourth or later, without previous CS	119 448	37.3	17.0	20.3
	Fourth or later, with previous CS	36 603	40.1	19.8	20.3
Maternal prepregnancy BMI	Underweight (<18.5)	71 274	36.0	16.9	19.1
	Normal (18.5–24.9)	745 076	34.1	16.2	17.9
	Overweight (25–29.9) or Obese I (30–34.9)	545 699	38.3	19.4	18.9
	Obese II (35–39.9)	78 326	42.1	21.8	20.3
	Obese III (≥40)	50 704	48.7	26.9	21.8
	Unknown	113 695	37.2	16.8	20.4
Tobacco use during pregnancy	Yes	129 983	51.7	24.2	27.5
	No	1 474 791	35.3	17.4	17.9

BC, birth certificate; CS, cesarean delivery; NH, non-Hispanic.
[a] Based on whether the father's age is reported on the BC.

61 per 1000 in level III hospitals, and from 2 to 41 per 1000 in level I hospitals.

DISCUSSION

We found a 14-fold variation in Florida hospital rates of total unexpected newborn complications in 2004 to 2013. Based on the high proportion of variation explained by hospital factors, there are potential opportunities for quality improvement (QI). Before this study, the CMQCC reported large variation in complication rates among 220 California hospitals (95th percentiles for total complication rates ranged from 10 to 80 per 1000). The measure had high intrahospital consistency over three 6-month periods (mean reliability: 0.92) and tracked closely to hospitals in the US East Coast in a comparison trial by gestational age. The CMQCC report did not focus on exploring risk factors and reasons for hospital variation in complication rates.[9,15] We quantified the contribution of individual and hospital factors to hospital variation and discuss implications for improvement.

First, although severe and moderate complications were classified based on the level of hospital morbidity, the 2 measures that made up total unexpected complications do not appear to reflect a continuum of hospital quality. A hospital's rate for 1 type of complication did not predict its rate for the other. Among hospitals with high rates of total complications, some had high severe complication rates and others had high moderate complication rates; few had both. Furthermore, significant hospital factors differed by type of complication, suggesting that high hospital rates of severe or moderate complications imply different QI issues.

TABLE 3 Unexpected Complication Rates by Health Service Factors and Year (Florida, 2004–2013)

		Term Births	Unexpected Complication Rate (per 1000 Live Births)		
			Total	Severe	Moderate
Total		1 604 774	36.7	18.0	18.7
Individual					
Adequacy of prenatal care (GINDEX)	Intensive or adequate	550 705	34.4	17.0	17.4
	Intermediate	593 786	36.2	18.6	17.6
	Inadequate	315 005	38.3	20.3	18.0
	No care	15 237	70.6	38.1	32.5
	Unknown	130 041	40.7	20.3	20.4
Timing or reason for delivery initiation	Spontaneous, 37–38 wk	264 071	41.3	21.9	19.4
	MI induction or CS at 37–38 wk[a]	139 893	53.3	27.1	26.2
	NMI induction at 37–38 wk	49 843	30.4	16.6	13.8
	NMI CS at 37–38 wk (without labor)	78 714	30.8	14.3	16.5
	≥39 wk, with medical indication[a]	468 900	43.6	20.9	22.7
	≥39 wk, without medical indication	603 353	26.7	14.4	12.3
Delivery day of week	Weekday (Monday–Friday)	1 314 540	35.7	18.2	17.5
	Weekend (Saturday–Sunday)	290 234	41.1	21.0	20.1
Hospital					
Level of NICU and birth volume quartile[b]	Level I, bottom	42 392	40.0	9.5	30.5
	Level I, second–third	189 370	39.0	14.0	25.0
	Level I, top	185 799	36.0	15.8	20.2
	Level II, bottom	63 262	46.5	21.5	25.0
	Level II, second–third	247 933	38.7	18.9	19.8
	Level II, top	197 853	28.6	16.3	12.3
	Level III, bottom	89 239	32.2	16.6	15.6
	Level III, second–third	315 002	38.4	23.8	14.6
	Level III, top	273 924	36.3	21.2	15.1
Medicaid births percentage quartile[b]	Bottom	624 678	28.9	15.5	13.4
	Second–third	829 573	40.5	20.6	19.9
	Top	150 523	48.6	22.0	26.6
Florida geographic location[c]	Northwestern	110 853	41.8	21.1	20.7
	Northeastern	187 260	36.9	18.2	18.7
	Central	391 681	35.7	19.8	15.9
	Western	347 089	32.9	17.5	15.4
	Eastern	332 057	32.4	17.6	14.8
	Southern	235 834	47.6	19.6	28.0
Year of delivery	2004–2005	317 311	36.6	19.4	17.2
	2006–2007	337 561	34.3	17.7	16.6
	2008–2009	329 516	36.0	18.2	17.8
	2010–2011	311 457	38.2	18.8	19.4
	2012–2013	308 929	38.6	19.5	19.1

CS, cesarean delivery; GINDEX, Graduated Index of Prenatal Care Utilization; MI, medically indicated.

[a] The Joint Commission's *List of Conditions Possibly Justifying Elective Delivery Prior to 39 Weeks Gestation,* v2015A1; Supplemental Table 5.

[b] Specific to year of birth.

[c] Adapted from the American Congress of Obstetricians and Gynecologists District XII (Florida) map (Supplemental Table 6).

Second, hospital differences in unexpected complications seem to be driven more by identified hospital factors than individual factors. Substantial reductions in observed hospital variation in complication rates were achieved only by adjusting for hospital geographic location, level of care or birth volume, and percentage of Medicaid births. Specific diagnosis categories explained the hospital factors that contributed to variation in severe and moderate complications. For instance, differences by hospital geographic location were driven

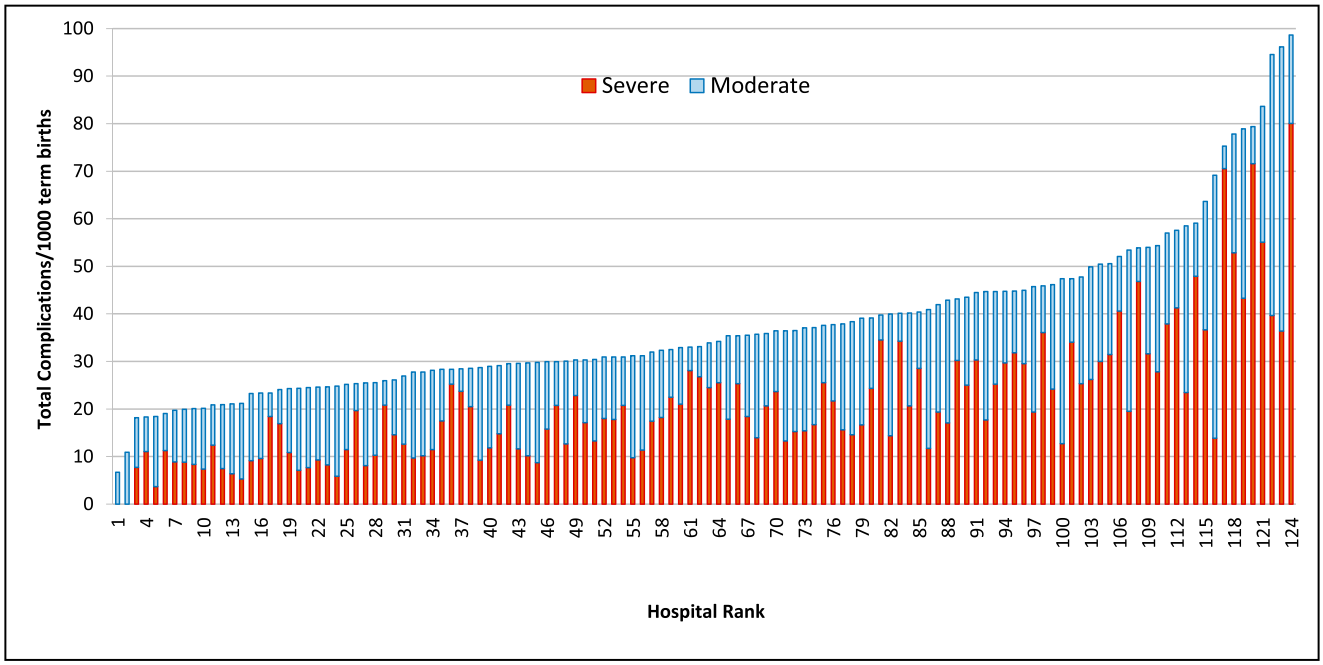

FIGURE 1

Hospital rates of unexpected newborn complications (Florida, 2004–2013). Rates of total complications varied widely across Florida hospitals. High rates were driven by severe complication rates in some hospitals and by moderate complication rates in others.

predominantly by infection rates (higher in southern Florida hospitals), and differences by level of care were influenced largely by neonatal transfer rates (higher in level I hospitals). Differences by percentage of Medicaid births were influenced by hospital transfer and infection rates (higher in high-Medicaid hospitals and possibly reflecting hospital level of care). These data imply that hospital differences in complication rates may be related to differences in quality of care and coding practice. In a previous investigation of Florida late preterm births, our group identified differences in coding accuracy for labor and delivery characteristics (eg, induction) between hospitals with high versus low rates of primary late preterm cesarean delivery.[11] It is possible that hospital differences in coding of newborn complications contribute to some of the variation in complication rates. However, based on the large variation, it is unlikely that differences in coding practice alone account for all the differences. Only published US studies assessing coding accuracy of hospital discharge or birth certificate for mortality and congenital anomalies, and not other newborn complications, were identified.[16] The first step in QI efforts by individual hospitals or systems should be directed at validating the clinical findings.

Third, hospital performance comparisons that used the unexpected complications measure may be most appropriately done by level of care. We reported that delivering in level I hospitals was a significant factor for severe complications, whereas delivering in level III hospitals increased the odds of moderate complications. Although neonatal transfers explained the high rates of severe complications in level I hospitals, transfer rates varied widely by hospital at that level. This finding suggests that transferring neonates to another hospital is not just a capacity issue with basic-level hospitals. Level III hospitals, on the other hand, had high rates and high variation in moderate respiratory problems and unspecified long neonatal LOS, suggesting that high complication rates in this group are not simply an issue of referrals to higher-level hospitals. Functional capabilities may be fundamentally different for hospitals with basic care level versus high-level NICU hospitals,[17] but there seem to be quality issues to be addressed at each level.

Finally, additional opportunities for prevention may involve targeting potentially modifiable factors at the individual level, related to early-term gestation and medical indications for delivery, lack of prenatal care, nulliparity, obesity, and smoking. These factors are consistent with previous studies reporting risk factors for adverse neonatal outcomes such as respiratory difficulties, NICU admissions, preterm birth, and low birth weight.[6,18–23] Of note, our findings for early-term NMI inductions, a moderate factor for both severe and moderate complications, differ from those of

a recent Florida study of singleton term and postterm deliveries. Using data from 2005 to 2009, Salemi et al[22] found that NMI inductions at 37 to 38 weeks did not increase the odds of neonatal respiratory morbidity or NICU admission relative to deliveries at ≥39 weeks. Two methodological differences might explain the different findings. First, the Salemi et al study population excluded mothers with chronic medical indications for early delivery, such as diabetes. Medical indications for early delivery included only acute conditions detected at the time of labor and delivery, such as vasa previa.[22] This population differed from our study population, which included mothers with both chronic and acute medical indications. Second, inductions at 37 to 38 weeks with medical indications identified at delivery were retrospectively excluded from the NMI early-term induction group but not from the ≥39 weeks reference group. For example, as reported in that study, deliveries with vasa previa were excluded from NMI deliveries at 37 to 38 weeks but not from the ≥39 weeks reference group.[22] In contrast, the ≥39 weeks reference group in our study excluded medical indications. The inclusion of medical indications in the reference group may have contributed to the null estimate of association in the Salemi et al study.

Our study was limited by the inability to assess the level of care of receiving hospitals for transfers. We received anecdotal reports from regional centers suggesting that almost all neonatal transfers during the first 4 days of life in Florida are to a higher-level hospital. It is unlikely that transfers in the study included a large number of back transfers among level III hospitals because 95% of transfers occurred within 4 days of birth, and transfers from level III hospitals were extremely rare. Another potential limitation is the use of birth certificate and maternal

TABLE 4 Unadjusted and aORs of Unexpected Complications in Term Newborns (Florida, 2004–2013)

	Total Complications (n = 58 886)		Severe (n = 28 853)	Moderate (n = 30 033)
	OR (95% CI)	aOR (95% CI)[a]	aOR (95% CI)[a]	aOR (95% CI)[a]
Age, y (reference: <20 y)				
20–29	0.89 (0.87–0.91)	1.10 (1.06–1.13)	1.11 (1.06–1.16)	1.09 (1.04–1.13)
30–39	0.82 (0.79–0.84)	1.18 (1.13–1.22)	1.20 (1.14–1.26)	1.15 (1.10–1.21)
≥40	0.88 (0.83–0.93)	1.22 (1.15–1.30)	1.28 (1.18–1.40)	1.17 (1.07–1.27)
Race or ethnicity (reference: NH white)				
NH black	0.94 (0.92–0.96)	0.84 (0.82–0.86)	0.97 (0.93–1.00)	0.74 (0.71–0.77)
Hispanic: Mexican	0.80 (0.77–0.83)	0.79 (0.75–0.82)	0.81 (0.76–0.86)	0.77 (0.73–0.82)
Hispanic: Puerto Rican	0.88 (0.85–0.92)	0.84 (0.80–0.87)	0.94 (0.89–1.00)	0.76 (0.71–0.80)
Hispanic: Cuban	0.90 (0.86–0.95)	0.84 (0.81–0.88)	0.89 (0.84–0.94)	0.80 (0.75–0.86)
Hispanic: Central or South American	0.81 (0.78–0.85)	0.83 (0.79–0.86)	0.88 (0.83–0.93)	0.79 (0.75–0.84)
Other Hispanic	0.87 (0.83–0.91)	0.83 (0.79–0.87)	0.87 (0.82–0.93)	0.79 (0.74–0.84)
Haitian	0.99 (0.94–1.03)	0.91 (0.87–0.96)	1.01 (0.94–1.08)	0.84 (0.79–0.90)
Other, NH	0.83 (0.80–0.87)	0.87 (0.83–0.91)	0.95 (0.89–1.01)	0.81 (0.76–0.86)
Not married	1.27 (1.25–1.29)	1.08 (1.06–1.11)	1.05 (1.02–1.09)	1.11 (1.08–1.14)
Father not acknowledged on BC[b]	1.27 (1.30–1.24)	1.12 (1.09–1.15)	1.11 (1.07–1.15)	1.12 (1.08–1.16)
Education (reference: college graduate)				
Less than high school	1.31 (1.28–1.34)	1.19 (1.16–1.23)	1.21 (1.15–1.26)	1.18 (1.13–1.23)
High school graduate or GED	1.26 (1.23–1.29)	1.15 (1.12–1.18)	1.16 (1.12–1.21)	1.14 (1.10–1.18)
Some college (no degree)	1.19 (1.16–1.23)	1.11 (1.08–1.14)	1.10 (1.05–1.14)	1.13 (1.08–1.17)
Insurance (reference: private)				
Medicaid	1.29 (1.27–1.31)	1.20 (1.17–1.22)	1.20 (1.16–1.24)	1.20 (1.16–1.23)
Self-pay	1.01 (0.97–1.06)	1.03 (0.98–1.08)	1.06 (0.99–1.13)	1.00 (0.94–1.07)
Other	1.25 (1.16–1.34)	1.23 (1.15–1.32)	1.24 (1.11–1.37)	1.23 (1.12–1.35)
Birth order and history (reference: second or third delivery, no previous CS)				
First delivery	1.42 (1.39–1.45)	1.41 (1.38–1.44)	1.60 (1.56–1.65)	1.25 (1.21–1.28)
Second or third delivery, previous CS	0.90 (0.87–0.93)	0.89 (0.86–0.92)	1.01 (0.97–1.06)	0.79 (0.75–0.82)
Fourth or later, no previous CS	1.14 (1.10–1.18)	1.02 (0.98–1.06)	1.01 (0.96–1.06)	1.03 (0.98–1.08)
Fourth or later, previous CS	1.21 (1.15–1.28)	1.07 (1.01–1.13)	1.14 (1.06–1.24)	1.01 (0.93–1.09)
BMI (reference: normal, 18.5–24.9)				
Underweight (<18.5)	1.03 (0.99–1.07)	0.96 (0.92–1.00)	0.95 (0.89–1.00)	0.96 (0.91–1.02)
Overweight or obese class I (25–34.9)	1.10 (1.08–1.12)	1.10 (1.08–1.13)	1.16 (1.13–1.20)	1.05 (1.02–1.08)
Obese class II (35–39.9)	1.21 (1.16–1.25)	1.16 (1.12–1.21)	1.24 (1.18–1.31)	1.09 (1.04–1.15)
Obese class III (≥40)	1.39 (1.33–1.45)	1.30 (1.25–1.36)	1.47 (1.39–1.56)	1.14 (1.07–1.21)
Unknown	1.17 (1.13–1.22)	1.13 (1.09–1.17)	1.13 (1.07–1.19)	1.13 (1.07–1.19)
Tobacco use (reference: no)	1.45 (1.41–1.49)	1.28 (1.24–1.32)	1.19 (1.14–1.24)	1.37 (1.32–1.42)
GINDEX (reference: intensive or adequate)				
Intermediate	0.99 (0.97–1.01)	1.00 (0.98–1.02)	1.00 (0.97–1.03)	1.00 (0.97–1.03)
Inadequate	1.04 (1.02–1.07)	1.04 (1.01–1.07)	1.02 (0.98–1.06)	1.06 (1.03–1.10)
No care	1.83 (1.72–1.95)	1.78 (1.66–1.90)	1.80 (1.63–1.98)	1.76 (1.61–1.92)
Unknown	1.13 (1.09–1.17)	1.12 (1.08–1.15)	1.12 (1.07–1.18)	1.11 (1.05–1.16)

TABLE 4 Continued

	Total Complications (n = 58 886)		Severe (n = 28 853)	Moderate (n = 30 033)
	OR (95% CI)	aOR (95% CI)[a]	aOR (95% CI)[a]	aOR (95% CI)[a]
Timing and reason for delivery initiation (reference: ≥39 wk, without medical indication)				
Spontaneous, 37–38 wk	1.58 (1.54–1.62)	1.54 (1.50–1.58)	1.62 (1.56–1.68)	1.46 (1.41–1.51)
MI induction or CS at 37–38 wk[c]	2.15 (2.09–2.21)	2.12 (2.06–2.18)	2.28 (2.19–2.38)	1.98 (1.90–2.06)
NMI induction at 37–38 wk	1.17 (1.11–1.24)	1.21 (1.14–1.28)	1.20 (1.11–1.30)	1.21 (1.13–1.30)
NMI CS at 37–38 wk (without labor)	1.18 (1.13–1.23)	1.38 (1.32–1.45)	1.55 (1.45–1.65)	1.23 (1.15–1.32)
≥39 wk, with medical indication[c]	1.69 (1.66–1.73)	1.56 (1.53–1.60)	1.81 (1.76–1.87)	1.36 (1.32–1.40)
Weekend (Saturday–Sunday) delivery	1.13 (1.11–1.15)	1.10 (1.08–1.12)	1.14 (1.11–1.18)	1.06 (1.03–1.09)
Hospital level of NICU and birth volume quartile (reference: level III, bottom quartile)[d]				
Level I, bottom	1.06 (0.92–1.22)	1.14 (0.99–1.30)	1.58 (1.31–1.91)	0.70 (0.56–0.87)
Level I, second–third	0.96 (0.85–1.08)	1.04 (0.93–1.17)	1.43 (1.22–1.69)	0.72 (0.60–0.85)
Level I, top	0.94 (0.83–1.05)	1.01 (0.90–1.13)	1.27 (1.08–1.49)	0.79 (0.67–0.93)
Level II, bottom	1.17 (1.03–1.32)	1.19 (1.05–1.34)	1.33 (1.13–1.56)	1.09 (0.91–1.29)
Level II, second–third	0.98 (0.88–1.09)	1.00 (0.90–1.11)	1.07 (0.92–1.25)	0.98 (0.84–1.13)
Level II, top	0.83 (0.74–0.92)	0.87 (0.78–0.96)	0.85 (0.73–0.99)	0.92 (0.79–1.07)
Level III, second–third	1.09 (1.01–1.18)	1.06 (0.98–1.14)	1.09 (0.97–1.22)	1.04 (0.94–1.15)
Level III, top	1.14 (1.04–1.25)	1.08 (0.98–1.19)	1.10 (0.96–1.27)	1.05 (0.93–1.20)
Hospital Medicaid births percentage quartile (reference: bottom quartile)				
Second–third	1.09 (1.04–1.14)	1.06 (1.01–1.11)	1.18 (1.10–1.26)	0.97 (0.91–1.03)
Top	1.19 (1.11–1.27)	1.17 (1.09–1.24)	1.42 (1.30–1.56)	0.95 (0.87–1.04)
Florida hospital geographic location (reference: Eastern)[e]				
Northwestern	1.37 (1.04–1.81)	1.19 (0.92–1.52)	1.31 (0.94–1.83)	1.02 (0.72–1.43)
Northeastern	1.24 (0.97–1.57)	1.14 (0.92–1.41)	1.26 (0.95–1.67)	0.98 (0.73–1.31)
Central	1.21 (0.99–1.48)	1.13 (0.94–1.35)	1.04 (0.82–1.33)	1.16 (0.91–1.49)
Western	1.11 (0.89–1.38)	1.05 (0.86–1.27)	1.07 (0.83–1.39)	0.99 (0.76–1.29)
Southern	1.62 (1.28–2.04)	1.65 (1.34–2.02)	1.91 (1.45–2.51)	1.29 (0.97–1.71)
Year of delivery (reference: 2006–2007)				
2004–2005	1.06 (1.03–1.08)	1.06 (1.03–1.09)	1.03 (0.99–1.07)	1.08 (1.04–1.12)
2008–2009	1.06 (1.03–1.08)	1.04 (1.02–1.07)	1.06 (1.02–1.10)	1.03 (0.99–1.06)
2010–2011	1.12 (1.10–1.15)	1.12 (1.09–1.15)	1.18 (1.13–1.22)	1.07 (1.03–1.11)
2012–2013	1.15 (1.12–1.18)	1.15 (1.11–1.18)	1.18 (1.13–1.22)	1.11 (1.07–1.16)

BC, birth certificate; CS, cesarean delivery; GINDEX, Graduated Index of Prenatal Care Utilization; MI, medically indicated; NH, non-Hispanic; OR, odds ratio (univariable model).

[a] OR adjusted for all variables shown: maternal age, race and ethnicity, marital status, father acknowledgment, maternal education level, health insurance, birth order and history, prepregnancy BMI, tobacco use, adequacy of prenatal care, timing and reason for delivery initiation, delivery day of week (weekday, weekend), hospital level of NICU and birth volume, hospital Medicaid births percentage, hospital geographic location, and year of delivery.

[b] Based on whether the father's age is reported on the BC.

[c] The Joint Commission's *List of Conditions Possibly Justifying Elective Delivery Prior to 39 Weeks Gestation,* v2015A1; Supplemental Table 5.

[d] Specific to year of birth.

[e] Adapted from the American Congress of Obstetricians and Gynecologists District XII (Florida) map (Supplemental Table 6).

hospital discharge records to identify unexpected complications. An intrinsic problem with these data is the underreporting or poor accuracy of some care processes, such as use of oxytocin and trial of labor.[11] The extent to which differences in these care processes contribute to hospital variation in neonatal complications is not well known.[24] Nonetheless, this currently may be the most appropriate available data for this type of investigation.[25] An additional limitation is the inability to adjust for mothers with >1 delivery over the study period. This limitation is not likely to have affected our estimates of association because complication rates were higher in first-time mothers.

CONCLUSIONS

Hospital characteristics contribute substantially to the variation in unexpected complication rates in Florida. Understanding hospital reasons for differences in rates of specific complication categories may be particularly useful to guide QI. Reasons for the differences may be related to both quality of care and coding practice. A hospital's first QI step should be to validate the clinical findings.

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ABBREVIATIONS

AHCA: Agency for Health Care Administration
aOR: adjusted odds ratio
CI: confidence interval
CMQCC: California Maternal Quality Care Collaborative
LOS: length of stay
NMI: non–medically indicated
QI: quality improvement

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