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Neonatal Intensive Care Variation in Medicaid-Insured Newborns: A Population-Based Study

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Objective To assess the contribution of maternal and newborn characteristics to variation in neonatal intensive care use across regions and hospitals.

Study design This was a retrospective population-based live birth cohort of newborn infants insured by Texas Medicaid in 2010-2014 with 2 subcohorts: very low birth weight (VLBW) singletons and late preterm singletons. Crude and risk-adjusted neonatal intensive care unit (NICU) admission rates, intensive and intermediate special care days, and imaging procedures were calculated across Neonatal Intensive Care Regions (n = 21) and hospitals (n = 100). Total Medicaid payments were calculated.

Results Overall, 11.5% of live born, 91.7% of VLBW, and 37.6% of infants born late preterm were admitted to a NICU, receiving an average of 2 days, 58 days, and 5 days of special care with payments per newborn inpatient episode of $5231, $128 075, and $10 837, respectively. There was little variation across regions and hospitals in VLBW NICU admissions but marked variation for NICU admissions in late preterm newborn infants and for special care days and imaging rates in all cohorts. The variation decreased slightly after health risk adjustment. There was moderate substitution of intermediate for intensive care days across hospitals (Pearson r VLBW −0.63 $P < .001$; late preterm newborn −0.53 $P < .001$).

Conclusions Across all risk groups, the variation in NICU use was poorly explained by differences in newborn illness levels and is likely to indicate varying practice styles. Although the “right” rates are uncertain, it is unlikely that all of these use patterns represent effective and efficient care. *(J Pediatr 2019;209:44-51)*.

Since the onset of neonatal intensive care in the mid-twentieth century, it has developed into a mature and widely available clinical service that has successfully reduced mortality and morbidity.[1] Robust growth in the number of patient beds and neonatal clinicians[2] has expanded services from primarily infants born very premature to a wider range of clinical problems. Today the majority of newborn infants admitted to neonatal intensive care units (NICUs) are of normal birth weight.[3,4]

Reflecting the initial clinical emphasis of NICUs, studies of neonatal intensive care have largely focused on infants of very low birth weight (VLBW; <1500 g) admitted to units participating in provider-based networks such as the Vermont Oxford Network[5] and the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development's Neonatal Research Network.[6] The few previous investigations of infants with birth weights ≥1500 g studied relatively small populations,[7-9] lacked an explicit population base,[8,10] or evaluated limited measures of care.[11] Across the full newborn population, the quality, outcomes, and efficiency of care remain poorly documented and understood.[12-18]

In this study, we describe patterns of hospital and professional care across regions and hospitals for the diverse population of Texas Medicaid-insured newborn infants. Medicaid insures >50% of all Texas births, and newborn infants receive care in >250 hospitals and 145 NICUs (2010-2014). Linking the Medicaid files to vital records provides maternal and newborn characteristics that can be used to develop risk-adjustment models addressing our primary research question, “Are differences in care largely due to patient factors reflecting health

CV	Coefficient of variation
NICR	Neonatal Intensive Care Region
NICU	Neonatal intensive care unit
VLBW	Very low birth weight

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status?" and the secondary question, "Do patient factors explain differences in care to a larger extent in high-risk compared with low-risk newborn infants?"

Methods

We developed a retrospective cohort of newborn infants insured by Medicaid who were born in Texas from January 1, 2010, to December 31, 2014, through the linkage of Texas Department of State Health Services Medicaid newborn enrollment files to natality records (92.8% linkage), mortality records for the first year of life (96% linkage), and maternal Medicaid enrollment records (88% linkage). Linkage rates varied across regions (79%-96%) but did not correlate with use rates (Spearman ≥0.1). These records were then joined to maternal and newborn facility (ie, hospital) and professional claims/encounters (**Appendix 1**; available at www.jpeds.com). Although about 60% of newborn care is paid through managed care plans, these plans report encounter records to Texas Medicaid with the same completeness as the care paid directly from Medicaid through claims submission. We excluded Medicaid insured infants who were <400 g at birth (n = 932); without either a facility or professional claim within 2 days of birth (n = 123 706); without a Texas county of birth (n = 1151); and those lacking relevant covariates used for risk adjustment (n = 1263). As early newborn deaths often lack associated claims, Medicaid-enrolled infants with dates of death within 2 days of birth but without claims were included in the cohort and counted as having a NICU admission (n = 832). The final cohort included 1 133 441 infants with annual cohort sizes ranging from 215 172 (2010) to 234 470 (2014). We also defined 2 singleton subcohorts: VLBW (400-1499 g; n = 12 826) and late preterm (late preterm newborn, ie, 34-36 weeks of gestation; n = 78 013) infants (**Table I**). Four hundred forty-nine infants were assigned to both late preterm newborn and VLBW cohorts.

Newborn Regional and Hospital Assignment

We assigned Texas counties to geographic markets for neonatal intensive care use using small area analysis methods.[19,20] The study used Texas Medicaid use data from calendar years 2011 to 2013 to identify newborn infants with special care facility use revenue codes 0172 to 0175. For each county where NICU-admitted newborn mothers resided, the percent of NICU admissions was calculated for

Table I. Texas Medicaid newborn study cohorts, 2010-2014

Characteristics	Cohorts* All live births (n = 1 133 441)	VLBW singletons (<1500 g) (n = 12 826)	Late preterm singletons (34-36 wk of gestation) (n = 78 013)
Newborn			
Birth weight, mean (SD), g	3205 (572)	1015 (306)	2689 (501)
Gestational age, mean (SD), wk	38.3 (2.1)	27.9 (3.6)	35.4 (0.8)
Males, n (%)	553 761 (48.9)	6219 (48.5)	36 319 (46.6)
Congenital anomalies, n (%)	54 387 (4.8)	3770 (29.4)	6536 (8.4)
Outborn (transferred), n (%)	14 041 (1.3)	1938 (15.1)	2430 (3.1)
Maternal			
Education, n (%)			
Less than high school	91 546 (8.1)	876 (6.8)	6259 (8.0)
Completed high school	697 190 (61.5)	7756 (60.5)	48 862 (62.6)
Completed college	344 705 (30.4)	4194 (32.7)	22 892 (29.3)
Black, n (%)	164 508 (14.5)	3322 (25.9)	13 404 (17.2)
Hispanic, n (%)	702 509 (62.0)	6746 (52.6)	47 158 (60.5)
Hypertension	139 292 (12.3)	4056 (31.6)	17 697 (22.7)
Breech	84 784 (7.5)	3776 (29.4)	7320 (9.4)
Fetal distress	57 350 (5.1)	973 (7.6)	4375 (5.6)
Oligohydramnios	2978 (0.3)	116 (0.9)	536 (0.7)
Polyhydramnios	156 (0.0)	24 (0.2)	155 (0.2)
Cord prolapse	140 339 (12.4)	878 (6.9)	8363 (10.1)
Rh isoimmunization	45 (0.0)	2 (0.0)	14 (0.0)
Placenta abruption	45 210 (4.0)	2326 (18.1)	6379 (8.2)
Antenatal steroids, n (%)	27 462 (2.4)	2151 (16.7)	3591 (4.6)
Maternal-newborn link, n (%)	946 311 (83.5)	9548 (74.4)	64 520 (82.7)
Number of newborns by assignment			
NICRs (N = 21)			
Mean (SD)	53 973 (67 666)	611 (841)	3715 (4615)
Median	23 297	266	1763
Range	7882-281 354	58-3470	564-19 663
100 largest hospitals			
Total newborns, n (%)†	900 048 (79.4)	11 843 (92.3)	64 586 (82.8)
Mean (SD)	9000 (7686)	118 (121)	646 (544)
Median	6754	79	428
Range	2697-49 816	11-582	193-2738

*All cohorts restricted to ≥400 g.
†Number and percent of all Texas Medicaid newborn study cohort newborns assigned to 100 largest hospitals.

the different counties that admitted its newborns. Each county with NICU admitted newborns was then assigned to the county that provided the greatest percent of its NICU admissions. The Neonatal Intensive Care Regions (NICRs) were required to have a minimum number of 500 NICU-admitted newborn infants from 2011 to 2013, a localization index of ≥70%, and ≥2 NICUs with at least 1 unit classified as a level III or IV NICU. Localization indices (ie, the percent of resident infants with a NICU admission who were admitted to a within-region NICU) indicated that a very high proportion of resident infants were admitted to a NICU within the region of residence (median 90%; range 74%-99%).[21] Infants also were assigned to the hospital where they had the greatest number of inpatient days during their newborn hospitalizations. Analyses at the hospital level were restricted to the 100 hospitals for each cohort with the greatest number of assigned infants. We classified units using the 2014 State of Texas Annual Hospital Survey definition, which identifies 4 levels of neonatal care similar to American Academy of Pediatrics guidelines.[22,23]

Measures of Newborn Care

Eight common newborn care events were identified in Medicaid claims/encounter records (Appendix 1). Event definitions were developed through review of previous studies,[24] and in consultation with neonatologist investigators and hospital billing personnel. A "special care day" was defined as an inpatient day in which either a facility or professional claim was billed at greater than "routine" level of care and was classified as an intensive day if the facility or professional claim was billed at the greatest (ie, intensive/critical) level. A NICU admission was defined if an infant had ≥1 professional claim at a non-routine level, or a facility claim at the greatest (ie, intensive/critical level), or the infant died in the first 5 days with or without a claim indicating such care. Imaging events were identified through Current Procedural Terminology codes (Appendix 1) on professional claims for chest films, abdominal films, magnetic resonance imaging of the head, and ultrasound scans of the head. For each imaging type, only 1 imaging event was counted per day. Events were counted for the newborn inpatient episode, defined as all inpatient days from birth until a discharge with a gap of 1 day from a subsequent admission (ie, transfers included). For special care days and imaging studies, denominators were adjusted for the number of days survived in the first 27 days.

Medicaid Payments

To estimate spending for newborn care,[25] we included infants with a paid facility claim >$0. Overall, 15% (n = 168 240) of infants were excluded (VLBW 10% and late preterm newborn 12%), focusing the analyses on infants with comprehensive spending records (n = 965 201). Total program payment/stay was estimated by summing the header paid amounts from the claims within a single stay. We did not include Medicaid payments to hospitals as part of other payment programs such as disproportionate share hospital payments. We excluded cases with outlying or improbable cost (<$25 or ≥$1 000 000 per stay) or length of stay (>365 days), which represented less than 0.85%.[26] All spending information was adjusted across using Medical Consumer Price Index to represent 2014 US dollars.

Risk Adjustment

To control measures of NICU care for differing illness severity across regions and hospitals, we developed models to adjust for illness levels before the initiation of medical care (Appendix 1). Briefly, NICU measures were adjusted in 3 steps. First, 27-day neonatal mortality was modeled for each cohort in a logit model. Neonatal mortality was used because it is an accurately measured outcome that is important, relatively frequent, and is used to assess NICU unit performance. Models were initially specified with independent variables meeting the following criteria: (1) exogenous to newborn medical care (ie, present before medical care was initiated), (2) a known association with neonatal mortality as reported in previous studies,[18,27,28] and (3) clinical and perinatal epidemiological plausibility. In addition, a dichotomous variable was included to indicate linkage with maternal claims (or not). Final models were highly predictive of observed mortality (c-statistic for all live births 0.912, VLBW 0.856, late preterm newborn 0.868). Using the models, we then estimated the predicted probability of 27-day mortality for each newborn assigned to the 3 cohorts (all infants, infants who were VLBW, and infants who were late preterm newborn). Because some important illnesses are not associated with heightened mortality, we tabulated diagnostic and procedure codes (Appendix 1) to assign presence/absence of a relevant diagnosis or a major procedure. In the second step, we specified fixed effect models with the newborn as the unit of analysis with the event as the dependent variable (ie, medical event), and the newborn risk scores, presence of diagnostic code, and presence of major procedure code, and regions or hospitals as independent variables. In the final step, we calculated adjusted rates.

Analyses of Study Measures

The primary results are presented as crude and risk-adjusted risk ratios and rates with 95% CIs. Measures of variation across regions and hospitals (eg, IQR, coefficient of variation [CV, defined as SD/mean * 100]) were calculated for adjusted rates.[29,30] We tested associations of special care day rates across hospitals with Spearman and weighted Pearson correlations.

Analyses were conducted in SAS Version 9.4 and Stata Version 15 (SAS Institute, Cary, North Carolina). The project was approved by the institutional review boards of Dartmouth College, the University of Texas Health Science Center (Houston), The University of Florida (Gainesville), and the Texas Health and Human Services Commission (Austin).

Results

State-Level Newborn Use and Medicaid Payments

Overall, 11.6% of Texas Medicaid–insured newborn infants, 91.7% VLBW, and 37.5% of infants who were late preterm newborn were admitted to a Level II-IV NICU, receiving on average 2.0, 58.3, and 4.6 special care days, respectively (**Table II**, available at www.jpeds.com).[29,30] Infants who were VLBW represented 9.0% of NICU admissions and 29.0% of special care days, but late preterm newborns represented 22.3% of NICU admissions and 16.0% of special care days.

In 2014, Texas Medicaid paid at least $1 059 624 661 for newborn care, of which $890 153 286 was paid to facilities and $169 471 375 was paid to clinicians. Eighty-four percent of these payments ($887 143 938) were for infants who received special care. This proportion was constant across all years (ie, 2010-2014). The mean payments were $5231 (SD $29 181) for all live births (2010-2014), $128 075 (SD $138 087) for VLBW, and $10 837 (SD $33 644) for late preterm newborn births.

Crude and Adjusted Use Rates Across NICRs

There was moderate (CV 10 to <20) to high (CV ≥20) variation in use rates across NICRs (**Figure 1** and **Table II**) with the exception of the rate of NICU admission for infants who were VLBW, where the state rate was 91.7% and range of the 10th-90th percentile was 82.4%-95.3%. For most events, adjustment for newborn illness levels at birth across NICRs decreased variation but only to a small degree. For example, for VLBW infants the CV (SD/mean * 100) for special care days remained unchanged (10) for crude and adjusted rates. After adjustment, the 10th and 90th percentiles were 51.5 and 63.8 days/newborn, respectively.

There were similar findings in the cohort of late preterm newborn infants where moderate-to-high regional variation was not explained by regional differences in newborn health risk. The variation, as an example, in the crude and adjusted percent admitted to a NICU was only slightly lower for adjusted rates (CV 15) compared with crude rates (CV 18). After adjustment, the 10th and 90th percentiles were 29.0% and 41.8% admitted, respectively.

Crude and Adjusted Use Rates Across 100 Large Texas Hospitals

Although the magnitude of newborn care variation was generally greater across hospitals than regions, a similarly low proportion of the variation was explained by differences in newborn health risk (**Table III** and **Figure 2**). Infants who were VLBW cared for in hospitals at the 90th percentile received 67.3 special care days (64.2 intensive) and 23.2 chest films, and those at the 10th percentile received 32.9 days (15.4 intensive) and 4.3 films (all adjusted rates). The adjusted proportion of infants who were VLBW receiving at least 1 MRI scan of the head varied across the 10th to 90th percentile of hospitals from 0% to 51.1%. For late preterm newborn infants, adjusted rates varied from 26.5% (10th percentile) to 44.9% (90th percentile) for NICU admission, 3.1-6.8 for special care days, and 0.3-1.7 for chest x-rays.

Patterns of variation in special care days raised the question whether there was substitution of intermediate for intensive days. We observed a low-to-moderate negative correlation between intensive and intermediate days for VLBW (Pearson $r = -0.63$; $P < .001$) and late preterm newborn infants ($r = -0.52$; $P < .001$) (**Figure 3**, available

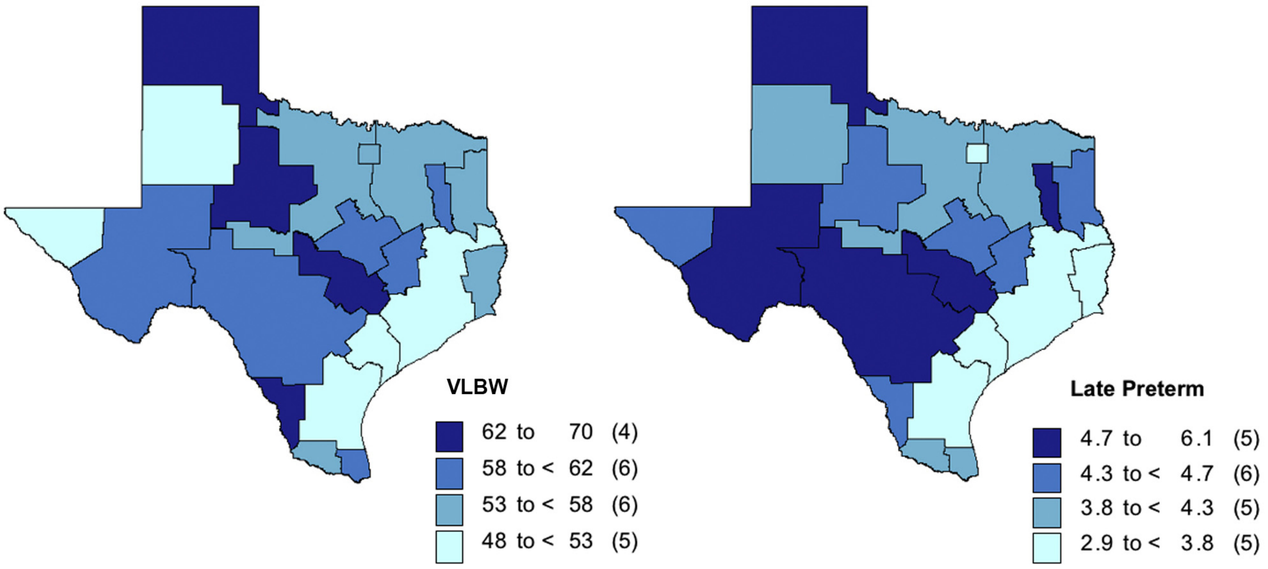


Figure 1. Adjusted special care days per newborn across NICRs (n = 21), Texas Medicaid-insured, 2010-2014.

Table III. Newborn initial hospital episode use rates across 100 largest hospitals, Texas Medicaid 2010-2014

		Hospital-level (N = 100) use rates (95% CI)					
		Median rates		10th and 90th adjusted rates		CV (magnitude: L, low; M, medium; H, high)	
Utilization measures	Texas	Crude	Adjusted	10th%	90th%	Crude	Adjusted
Live births (n = 1 133 441)							
NICU care, % admission	11.6 (11.5-11.6)	11.6 (10.7-12.5)	9.2 (7.9-10.7)	5.1 (4.3-6.2)	12.3 (10.6-14.2)	43 (H)	32 (H)
Total special care, days per newborn	2.0 (2.0-2.0)	1.5 (1.5-1.6)	2.0 (1.9-2.0)	1.1 (1.1-1.2)	2.9 (2.9-3.0)	70 (H)	34 (H)
Intensive care, days per newborn	1.4 (1.4-1.4)	1.0 (0.9-1.0)	0.9 (0.9-0.9)	0.2 (0.2-0.2)	1.5 (1.4-1.5)	93 (H)	59 (H)
Intermediate care, days per newborn	0.7 (0.7-0.7)	0.6 (0.6-0.6)	0.4 (0.4-0.5)	0.2 (0.2-0.2)	0.8 (0.8-0.9)	64 (H)	55 (H)
Chest x-ray, number per newborn	0.5 (0.5-0.5)	0.3 (0.3-0.3)	0.4 (0.4-0.4)	0.2 (0.2-0.2)	0.9 (0.8-0.9)	108 (H)	66 (H)
Abdominal x-ray, number per newborn	0.2 (0.2-0.2)	0.1 (0.1-0.1)	0.2 (0.2-0.2)	0.0 (0.0-0.1)	0.5 (0.4-0.5)	128 (H)	103 (H)
Head ultrasound, number per newborn	0.1 (0.1-0.1)	0.0 (0.0-0.0)	0.1 (0.1-0.1)	0.0 (0.0-0.0)	0.1 (0.1-0.1)	86 (H)	59 (H)
One or more MRIs, head, %	0.6 (0.6-0.7)	0.5 (0.4-0.7)	0.5 (0.4-0.8)	0.2 (0.1-0.3)	1.4 (1.1-1.8)	86 (H)	86 (H)
Medicaid payment crude, $	$5231	$3221 (IQR $3244)				136 (H)	–
VLBW (n = 12 826)							
NICU care, % admission	91.7 (90.1-93.4)	93.9 (71.1-114.0)	93.5 (71.2-119.0)	83.8 (57.0-106.7)	98.6 (81.9-146.1)	7 (L)	7 (L)
Total special care, days per newborn	58.3 (58.1-58.4)	54.3 (52.6-55.9)	53.9 (52.4-55.6)	32.9 (30.3-37.0)	67.3 (65.9-69.2)	34 (H)	29 (H)
Intensive care, days per newborn	50.0 (49.8-50.1)	45.9 (44.2-48.0)	46.2 (44.5-48.5)	15.4 (14.2-16.8)	64.2 (61.9-67.0)	47 (H)	43 (H)
Intermediate care, days per newborn	8.3 (8.3-8.4)	5.8 (5.1-6.6)	5.6 (5.0-6.4)	1.3 (1.0-1.6)	23.7 (22.2-25.4)	92 (H)	91 (H)
Chest x-ray, number per newborn	17.0 (16.9-17.1)	12.0 (11.5-13.0)	11.4 (10.1-12.7)	4.3 (3.2-5.7)	23.2 (21.3-26.7)	73 (H)	64 (H)
Abdominal x-ray, number per newborn	9.0 (9.0-9.1)	5.1 (4.6-6.0)	7.4 (6.5-8.6)	3.1 (2.2-3.9)	19.0 (17.4-21.1)	103 (H)	93 (H)
Head ultrasound, number per newborn	2.5 (2.5-2.5)	2.1 (1.8-2.5)	2.2 (1.7-2.6)	1.2 (0.8-1.7)	3.5 (3.0-4.3)	45 (H)	41 (H)
One or more MRIs, head %	19.5 (18.7-20.4)	17.0 (11.8-23.4)	16.6 (11.4-27.0)	0.0 (0.0-0.0)	51.1 (32.4-81.5)	90 (H)	90 (H)
Medicaid payment crude, $	$128 075	$87 293 (IQR $61 478)				63 (H)	–
Late preterm (n = 78 013)							
NICU care, % admission	37.5 (37.0-37.9)	40.7 (35.2-45.7)	36.7 (29.4-45.3)	26.5 (20.3-35.3)	44.9 (37.1-54.7)	27 (H)	19 (H)
Total special care, days per newborn	4.6 (4.6-4.6)	4.2 (4.0-4.3)	4.6 (4.4-4.8)	3.1 (2.8-3.4)	6.8 (6.6-7.0)	68 (H)	32 (H)
Intensive care, days per newborn	2.6 (2.6-2.6)	2.2 (2.1-2.4)	2.4 (2.1-2.6)	0.5 (0.4-0.6)	4.3 (4.0-4.8)	103 (H)	62 (H)
Intermediate care, days per newborn	2.1 (2.1-2.1)	2.0 (1.9-2.1)	2.4 (2.1-2.6)	0.6 (0.5-0.7)	3.6 (3.4-3.9)	61 (H)	53 (H)
Chest x-ray, number per newborn	1.0 (1.0-1.0)	0.6 (0.6-0.7)	0.7 (0.6-0.9)	0.3 (0.3-0.4)	1.7 (1.5-2.0)	122 (H)	63 (H)
Abdominal x-ray, number per newborn	0.4 (0.4-0.4)	0.2 (0.2-0.3)	0.3 (0.2-0.4)	0.1 (0.1-0.1)	0.7 (0.6-0.8)	176 (H)	99 (H)
Head ultrasound, number per newborn	0.1 (0.1-0.1)	0.1 (0.1-0.1)	0.1 (0.0-0.2)	0.0 (0.0-0.1)	0.3 (0.2-0.5)	94 (H)	84 (H)
One or more MRIs, head, %	1.1 (1.1-1.2)	0.6 (0.2-0.9)	0.8 (0.3-4.9)	0.0 (0.0-2.5)	3.0 (1.4-9.3)	183 (H)	186 (H)
Medicaid payment crude, $	$10 837	$7272 (IQR $5366)				92 (H)	–

MRI, magnetic resonance imaging; *X-ray*, radiograph.

Newborn inpatient episode is defined as all inpatient days from birth until a discharge with a gap of 1 day from a subsequent admission (ie, transfers included). Imaging procedures are counted as procedure days, which limits each newborn to only 1 procedure of a type (eg, chest x-ray) per day. CV is generally categorized as low (<10), medium (10 to < 20), and high (≥20).[29,30]

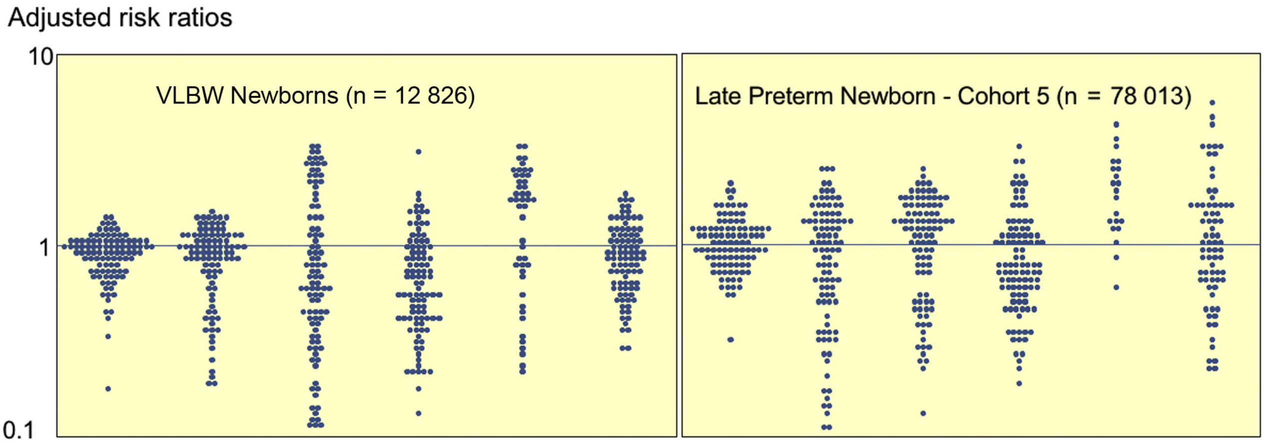
at www.jpeds.com), indicating that hospitals with greater numbers of intensive adjusted special care days generally had lower intermediate special care days. The scatter plots, however, show that there were many exceptions to this association.

Discussion

Medicaid-insured Texas newborn care differs widely across regions and hospitals. Health risk, as estimated by predicted 27-day mortality and the presence of diagnoses and procedures, varied substantially as well, but adjustment for these health indicators only slightly reduced the differences in use rates. This finding suggests that clinician practice styles and system factors are important determinants of care patterns. The exception was NICU admission rates in infants who are VLBW, where nearly all infants were admitted. Generally, the variation in adjusted use, as indicated by the CV, was slightly lower in infants born VLBW compared with infants born late preterm, but the magnitude of differences in adjusted rates across regions and hospitals as seen by comparing the 10th and 90th percentiles was high in both cohorts. The differences in the proportion of special care days billed at an intensive vs intermediate level that persists after adjustment is difficult to explain other than idiosyncratic provider practices and/or billing styles. Overall Medicaid payments were substantial, in excess of $1 billion dollars a year per annum with 86% of spending for infants who received special care.

Practice variation has been widely studied over the past 4 decades and is expected in any domain of care. The most comprehensive studies are in Medicare beneficiaries. Although a direct comparison is limited by the differences in population sizes, the magnitude of use variation is similar to variation observed in Texas Medicaid-insured infants.[29]

There are, however, 2 areas in which the care of newborn infants insured by Texas Medicaid stands out compared with Medicare beneficiaries. Patient factors, in particular health status, are responsible for much less of the variation in crude rates in Texas Medicaid than in Medicare.[31] The reason for this may be the near sole reliance of Medicare risk adjustment on claim diagnoses, which have been shown to "overadjust" measures because diagnoses are



	VLBW: Special Care Days			VLBW: Chest X-Rays	VLBW: % Head MRI	VLBW: Head Ultrasounds	Late Preterm: Special Care Days			Late Preterm: Chest X-Rays	Late Preterm: % Head MRI	Late Preterm: Head Ultrasounds
	Overall	*Intensive*	*Intermediate*				*Overall*	*Intensive*	*Intermediate*			
	58.3	50.0	8.3	17.0	19.5	2.5	4.6	2.6	2.1	1.0	1.1	0.1
CV	29	43	91	64	90	41	32	62	53	63	186	84
90th %	67.3	64.2	23.7	23.2	51.1	3.5	6.8	4.3	3.6	1.7	3.0	0.3
10th %	32.9	15.4	1.3	4.3	0.0	1.2	3.1	0.5	0.6	0.3	0.0	0.0

Figure 2. Adjusted risk ratios for 100 Texas hospitals, representing 92% of VLBW and 82% of late preterm Medicaid-insured newborns, 2010-2014. Each hospital is represented by *one dot*. The y-axis shows the ratio of the hospital adjusted rate to the hospital closest to the overall State rate. *MRI*, magnetic resonance imaging.

more frequent in settings where beneficiaries receive more care.[32-34] In our study, most of the neonatal risk adjustment explanatory power is from either maternal and newborn characteristics found in the natality file (eg, maternal education, newborn birth weight, and gestational age) or maternal claims (eg, antenatal steroids, hypertension), which are exogenous to newborn care. Another distinguishing feature of newborn infants insured by Medicaid is that the health outcome implications of variation in care extends for a much longer period than for elderly patients.

Our findings both complement and extend previously published studies. Geographic and provider variation in NICU admission rates have been found in studies using the US natality file[35,36] and other datasets.[37-39] We found greater rates of NICU admissions for infants who are VLBW compared with the few other population-based states.[35,36] In the study by Ziegler et al of 19 hospitals, the NICU admission rates for births ≥35 weeks of gestation was unexplained by differences in absolute or relative cause for admission.[37] In a larger study by Schulman et al from the California Perinatal Quality Care Collaborative, NICU admission rates of infants ≥34 weeks of gestation were negatively associated with the percent of infants meeting definitions of high illness severity.[38] Other studies from the California Perinatal Quality Care Collaborative described a 40-fold variation in NICU antibiotic use unexplained by proven infection or other factors.[40] Similarly, the high variation that was observed in the length of stay in infants weighing ≤1000 g at birth was unrelated to unit mortality rates.[41]

This study has some limitations. The cohort was restricted to Medicaid-insured infants, and although this restriction increases the study's internal validity when making comparisons across regions and hospitals, it limits inference to non-Medicaid populations. Generalizability to other states is also uncertain. Linkage with natality file records was not possible for about 7% of the Medicaid enrollment file records, which may limit the study's generalizability. Observational studies can never assert that adjustment includes all relevant patient factors, and this study is no exception. Short of randomization to hospitals, we believe our methods reflect the best available risk adjustment methods applicable to both low and high-risk cohorts. The adjustment models rely primarily on maternal and newborn characteristics from the natality file that are unaffected by newborn care. The inclusion of newborn diagnoses and procedures adds further health status information but is likely to overadjust with a bias to lower reported variation, given that it can reflect differing quality of care and diagnostic practices.[32-34] Finally, the definition of a NICU admission is based on study team consensus, instead of direct comparison with hospital records. Our results, however, are robust to differing NICU admission definitions that were tested.

The causes of variation in newborn care have been poorly studied, and for this reason caution should be exercised in applying causal frameworks from better studied populations (eg, Medicare) to newborn infants.[29] There is strong evidence that NICU beds and neonatologists are not located in regions with greater perinatal risk,[36,42] and some research suggests that NICU bed supply influences NICU admission rates and length of stay.[24,36,43,44] Differing practice styles also are likely to partially explain unwanted variation.[45]

The consequences of varying patterns of care is equally important and just as poorly understood. Low-risk infants are often identified as populations where there may be the greatest opportunity to reduce levels of care without harm, but there are only a few studies for any newborn cohort that support changes in current practice patterns.[9,46,47]

Risk adjusted use rates vary across regions and hospitals for both high and low risk newborn infants, and are therefore likely to indicate varying practice styles. Although the "right" rates are uncertain, these diverse use patterns are unlikely to represent effective and efficient care. ■

*List of additional members of the Texas Neonatal Intensive Care Unit Project Team is available at www.jpeds.com (**Appendix 2**).*

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50 Years Ago in *The Journal of Pediatrics*

Epidemiology of Diphtheria—Role of Cutaneous Infection

Blattner RJ. J Pediatr 1969;74:991-3

Despite reduction in the disease burden of diphtheria since the introduction of effective vaccine over the last 50 years, the epidemiology of the disease remains an area of concern, with outbreaks of the disease occurring intermittently in different parts of the world. Blattner, 50 years ago in *The Journal*, commented on a close association between the clinical or inapparent cutaneous diphtheria infection with pharyngeal disease outbreaks. The editorial highlighted that poor immune status may convert nontoxigenic skin bacterial flora into toxigenic strains, highlighting the importance of vaccination for preventing diphtheria.

Fifty years later, cutaneous diphtheria is still prevalent in tropical countries. The exact prevalence and patterns of cutaneous disease among populations over time are not known due to the similarity and coexistence with other cutaneous infections and nonavailability of a standard clinical definition. Cutaneous disease serves as a reservoir of toxigenic strains and an important source of spread. In developed nations with good immune status, cutaneous diphtheria usually does not translate to pharyngeal or systemic disease, probably due to an exaggerated antibody response.

In 1974, the World Health Organization incorporated the DPT (diphtheria, pertussis, and tetanus) vaccine into the expanded program of immunization, leading to a >90% decline in diphtheria worldwide.[1] In the 1990s, epidemics of diphtheria in the Russian Federation and the former Soviet Republics demonstrated the changing disease epidemiology; this epidemic involved adolescents and adults more than children. More than 157 000 cases and 5000 deaths were reported. There has been no significant decline in the worldwide incidence of diphtheria in the past decade; the majority of cases occur in South East Asia and India. Failure to vaccinate and increasing susceptibility due to waning immunity over years are responsible.[2]

The US Advisory Committee on Immunization Practices has recommended decennial boosters of tetanus–diphtheria (Td) to boost diphtheria immunity among adults of all ages. Another strategy is to replace adult vaccination with tetanus–diphtheria rather than tetanus toxoid (TT) at every opportunity. Developing nations also need to implement these strategies, in addition to improving routine immunization; these appear to be the most effective steps toward controlling intermittent epidemics.

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Appendix 2

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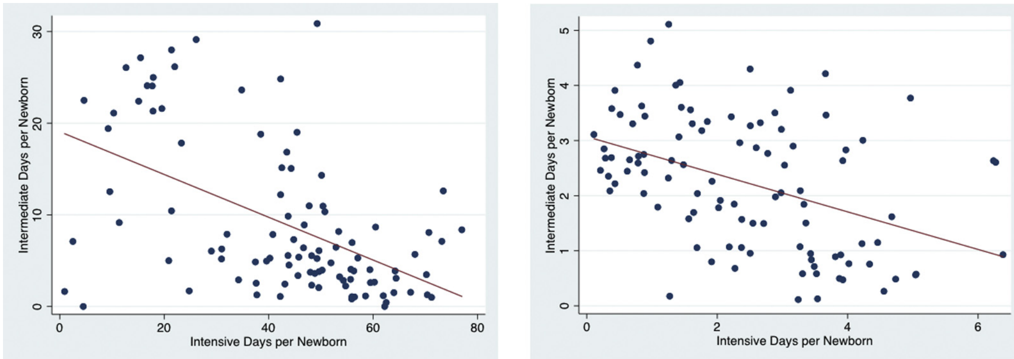

VLBW

Weighted Pearson r = -0.63 (*P* < .001)
Spearman rho = -0.48 (*P* < .001)

Late Preterm

Weighted Pearson r = -0.52 (*P* < .001)
Spearman rho = -0.44 (*P* < .001)

Figure 3. Association of adjusted intensive to adjusted intermediate special care days for 100 Texas hospitals, representing 92% of VLBW and 82% of late preterm Medicaid-insured newborns, 2010-2014.

Table II. Newborn hospital episode use rates across NICRs, Texas Medicaid 2010-2014

		NICR (N = 21) level use rates (95% CI)					
		Median rates		10th and 90th adjusted rates		CV (magnitude: L, low; M, medium; H, high)	
Utilization measures	Texas	Crude	Adjusted	10th%	90th%	Crude	Adjusted
Live births (n = 1 133 441)							
NICU care, % admission	11.6 (11.5-11.6)	11.0 (10.8-11.2)	10.2 (9.8-10.6)	8.2 (7.8-8.7)	13.0 (12.2-13.3)	19 (M)	20 (H)
Total special care, days per newborn	2.0 (2.0-2.0)	2.0 (1.9-2.0)	2.1 (2.1-2.2)	1.9 (1.8-1.9)	2.6 (2.6-2.6)	19 (M)	15 (M)
Intensive care, days per newborn	1.4 (1.4-1.4)	1.4 (1.3-1.4)	1.4 (1.4-1.4)	0.9 (0.9-1.0)	1.6 (1.6-1.7)	25 (H)	25 (H)
Intermediate care, days per newborn	0.7 (0.7-0.7)	0.6 (0.6-0.6)	0.7 (0.6-0.7)	0.4 (0.4-0.4)	0.9 (0.8-0.9)	45 (H)	40 (H)
Chest x-ray, number per newborn	0.5 (0.5-0.5)	0.4 (0.4-0.5)	0.5 (0.5-0.5)	0.4 (0.4-0.4)	0.8 (0.7-0.8)	34 (H)	27 (H)
Abdominal x-ray, number per newborn	0.2 (0.2-0.2)	0.2 (0.2-0.2)	0.2 (0.2-0.2)	0.2 (0.2-0.2)	0.3 (0.3-0.3)	55 (H)	40 (H)
Head ultrasound, number per newborn	0.1 (0.1-0.1)	5.7 (5.6-5.9)	6.8 (6.3-7.4)	4.5 (4.1-5.1)	9.9 (9.2-10.8)	40 (H)	32 (H)
One or more MRIs, head, %	0.6 (0.6-0.7)	0.5 (0.4-0.5)	0.6 (0.5-0.7)	0.3 (0.3-0.5)	1.1 (0.9-1.3)	58 (H)	52 (H)
Medicaid payment crude, $	$5231	$ 4310 (IQR $1533)				33 (H)	–
VLBW (n = 12 826)							
NICU care, % admission	91.7 (90.1-93.4)	89.7 (76.8-100.5)	89.3 (76.8-101.6)	82.4 (67.5-91.7)	95.3 (85.7-114.0)	6 (L)	6 (L)
Total special care, days per newborn	58.3 (58.1-58.4)	58.9 (57.9-59.6)	57.9 (56.8-59.0)	51.5 (50.4-52.6)	63.8 (62.3-65.5)	10 (M)	10 (M)
Intensive care, days per newborn	50.0 (49.8-50.1)	50.2 (49.6-51.4)	47.3 (45.3-49.3)	35.5 (33.9-37.3)	54.5 (52.1-57.4)	19 (M)	19 (M)
Intermediate care, days per newborn	8.3 (8.3-8.4)	6.8 (6.5-7.1)	7.1 (6.7-7.6)	4.1 (3.8-4.4)	16.5 (15.3-17.8)	67 (H)	67 (H)
Chest x-ray, number per newborn	17.0 (16.9-17.1)	15.9 (15.3-16.6)	17.0 (16.8-17.8)	11.3 (10.9-11.8)	23.9 (22.5-25.4)	26 (H)	26 (H)
Abdominal x-ray, number per newborn	9.0 (9.0-9.1)	7.7 (7.4-8.2)	7.3 (7.0-7.6)	4.9 (4.6-5.1)	11.6 (11.1-12.2)	43 (H)	40 (H)
Head ultrasound, number per newborn	2.5 (2.5-2.5)	2.4 (2.2-2.6)	2.4 (2.2-2.6)	1.7 (1.4-1.9)	3.3 (3.1-3.6)	26 (H)	25 (H)
One or more MRIs, head, %	19.5 (18.7-20.4)	12.7 (7.7-17.8)	14.4 (9.0-22.2)	8.7 (5.1-14.3)	41.1 (30.9-54.8)	70 (H)	68 (H)
Medicaid payment crude, $	$128 075	$121 073 (IQR $32 942)				22 (H)	–
Late preterm (n = 78 013)							
NICU care, % admission	37.5 (37.0-37.9)	36.6 (34.8-40.1)	34.9 (32.0-37.6)	29.0 (25.6-32.6)	41.8 (38.7-46.3)	18 (M)	15 (M)
Total special care, days per newborn	4.6 (4.6-4.6)	4.5 (4.4-4.6)	4.3 (4.2-4.5)	3.5 (3.3-3.6)	5.3 (5.2-5.4)	19 (M)	18 (M)
Intensive care, days per newborn	2.6 (2.6-2.6)	3.1 (3.0-3.1)	2.5 (2.4-2.5)	1.7 (1.6-1.7)	3.3 (3.2-3.5)	32 (H)	33 (H)
Intermediate care, days per newborn	2.1 (2.1-2.1)	1.7 (1.6-1.7)	1.6 (1.5-1.7)	1.1 (1.0-1.2)	2.6 (2.5-2.7)	38 (H)	37 (H)
Chest x-ray, number per newborn	1.0 (1.0-1.0)	0.9 (0.8-0.9)	0.9 (0.8-1.0)	0.6 (0.6-0.7)	1.4 (1.3-1.5)	34 (H)	33 (H)
Abdominal x-ray, number per newborn	0.4 (0.4-0.4)	0.3 (0.3-0.4)	0.4 (0.4-0.4)	0.3 (0.2-0.3)	0.5 (0.5-0.6)	59 (H)	46 (H)
Head ultrasound, number per newborn	0.1 (0.1-0.1)	0.1 (0.1-0.1)	0.1 (0.1-0.1)	0.1 (0.0-0.1)	0.2 (0.2-0.3)	68 (H)	57 (H)
One or more head MRI, %	1.1 (1.1-1.2)	1.3 (0.8-1.6)	1.1 (0.8-1.4)	0.7 (0.4-1.0)	1.8 (1.1-2.9)	39 (H)	45 (H)
Medicaid payment crude, $	$10 837	$10 195 (IQR $2495)				22 (H)	–

MRI, magnetic resonance imaging.
Newborn inpatient episode is defined as all inpatient days from birth until a discharge with a gap of 1 day from a subsequent admission (ie, transfers included). Imaging procedures are counted as procedure days, which limits each newborn to only 1 procedure of a type (eg, chest x-ray) per day. CV is generally categorized as low (<10), medium (10 to < 20), and high (≥20).[29,30]