

# Characteristics and health care utilization of otherwise healthy commercially and Medicaid-insured preterm and full-term infants in the US

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**Purpose:** This study examined health care utilization and costs during the first year of life for preterm and full-term infants in the US.

**Subjects and methods:** Preterm (<37 weeks gestational age [GA]) and full-term infants born 2003 to 2012 without complex medical conditions were identified in the MarketScan<sup>®</sup> Commercial and Multi-State Medicaid claims databases using ICD-9-CM diagnosis and diagnosis-related grouping codes. Inpatient and outpatient claims from birth through the first year were analyzed for preterm and full-term subgroups. Results were stratified by payer.

**Results:** There were 1,692,935 commercially insured infants (12.5% preterm) and 1,873,324 Medicaid-insured infants (13.9% preterm). The majority (>75%) of preterm infants were admitted to the neonatal intensive care unit during their birth hospitalization. Generally, mean length of stay and costs for birth hospitalizations increased with decreasing GA. The average cost of a birth hospitalization was US \$62,931 (SD \$134,347) for commercially insured preterm infants and \$43,858 (SD \$115,412) for Medicaid-insured preterm infants compared to \$2,401 (SD \$7,399) and \$1,894 (SD \$5,444) for commercially insured and Medicaid-insured full-term infants, respectively. Post-neonatal hospitalization rates increased as GA decreased (in full-term to <29 weeks GA: commercial = 3.3%–19.5%; Medicaid = 6.1%–26.2%). Preterm infants had greater average numbers of outpatient office visits and pharmacy claims than full-term infants. Following birth discharge, mean monthly health care costs per infant increased as GA decreased (commercial = \$334 to \$3,126; Medicaid = \$205 to \$2,473).

**Conclusion:** During the first year of life, post-neonatal hospitalization rates, outpatient office visits, pharmacy claims, and monthly costs increased as GA decreased.

**Keywords:** claims database, premature, birth hospitalization, health care costs

## Introduction

In 2014, nearly 4 million births were registered in the US.<sup>1</sup> Approximately 10% of these infants were born preterm, defined as <37 weeks gestational age (wGA).<sup>1</sup> Infants who are born prematurely have longer, more complicated, and more costly birth hospitalizations than full-term infants.<sup>2,3</sup> A 2013 March of Dimes study reported that birth hospitalization costs for preterm or low birth weight infants average ~US \$54,000, compared with \$4,400 for infants with uncomplicated births.<sup>4</sup> The financial impact of preterm birth is considerably greater when costs associated with the mother's hospitalization and the preterm infant's increased utilization of health care services after discharge from the birth hospitalization are considered.<sup>4</sup>

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Health care utilization and direct medical costs from birth through the first year of life likely differ depending on gestational age within the group of preterm infants and by insurer (ie, private or public), but prior studies, including the March of Dimes analysis, have not examined costs from this perspective. In addition, although preterm infants have been shown to use more health care resources following birth than full-term infants, these analyses provide an incomplete perspective on current costs because they used older data, analyzed relatively short follow-up windows, or grouped all preterm infants into a single cohort that ignores the potential resource use differences among infants born at different gestational ages.<sup>5-7</sup> Therefore, the objectives of this analysis were 1) to characterize birth hospitalizations in terms of the length of stay (LOS), neonatal intensive care unit (NICU) admissions, and costs and 2) to describe trends in health care utilization during the first year of life by gestational age for commercially insured and Medicaid-insured infants in the US.

## Subjects and methods

### Data source

This retrospective cohort analysis used the Truven Health Analytics MarketScan<sup>®</sup> Commercial Claims and Encounters and Multi-State Medicaid Databases. These databases contain the inpatient and outpatient medical and outpatient prescription drug data of enrollees, along with demographic and enrollment information. The commercial database includes enrollees from over 300 self-insured employers served by over 25 health plans. The publicly funded Medicaid database includes enrollees with Medicaid insurance from 10–15 states; the number of states and geographic mix vary by year.

These two databases include data from a variety of health plan types, including fee-for-service and managed care plans. Between 1995 and 2015, ~132 million enrollees were included in the commercial database, and ~40 million enrollees were included in the Medicaid database. The data were previously collected and statistically de-identified and are compliant with the de-identification conditions set forth in Sections 164.514 (a)-(b)1ii of the Health Insurance Portability and Accountability Act of 1996 Privacy Rule. The provisions in the Privacy Rule allow for use of health information that neither identifies nor provides a reasonable basis to identify an individual; therefore, approval from an institutional review board was not sought.

### Study population

We identified infants born between January 1, 2003, and December 31, 2012, in the commercial and Medicaid

databases by evaluating ICD-9-CM diagnosis codes or diagnosis-related groupings (DRGs) on inpatient claims. Infants were included in the study if they were discharged from their birth hospitalization alive. Infants with medical or pharmacy claims indicative of rare, complex medical conditions (eg, cystic fibrosis, immunodeficiency, organ transplants, congenital anomalies of the respiratory system, neuromuscular disease, other neuromuscular, immunological, or genetic conditions), chronic lung disease, or congenital heart disease were excluded. These infants may use more health care resources because of their conditions, and therefore could potentially bias the results with higher estimates of health care utilization and costs. Evidence of cystic fibrosis, Trisomy 21, immunodeficiencies, congenital lung anomalies, neuromuscular disease, and other genetic conditions was based on diagnosis codes, whereas organ transplant was identified by diagnosis or procedure codes. Chronic lung disease of prematurity or congenital heart disease were identified through combinations of diagnosis codes, procedure codes, and outpatient medications ([Table S1](#) shows code lists).

Infants in the study populations were classified as preterm or full-term based on ICD-9-CM diagnosis codes and DRG codes on medical claims (Table S1). Preterm infants were further classified by gestational age: <29 wGA, 29–30 wGA, 31–32 wGA, 33–34 wGA, 35–36 wGA (based on granularity available in ICD-9-CM diagnosis codes), unknown gestational age (ie, DRG indicates preterm but no ICD-9-CM diagnosis code for specific gestational age). Full-term infants were classified as full-term with major health problems and full-term without major health problems based on DRG coding. Diagnosis or DRG codes do not differentiate between full-term and post-term; therefore, the full-term cohort likely also includes post-term infants. Sex, region (commercial only), and race (Medicaid only) were determined from enrollment information, and evidence of comorbid conditions was based on diagnoses during the first 3 months of life.

### Characteristics of birth hospitalization

Several characteristics of birth hospitalization related to complexity of birth history were measured. LOS was measured as the total number of days hospitalized from birth to discharge. Admission to the NICU was identified based on procedure codes and revenue codes. Cost of hospitalization was captured and represents the paid amount, including both insurer- and patient-paid portions, on claims for birth hospitalization; costs were adjusted to 2017 US dollars using the Medicare Care Component of the Consumer Price Index.

## Health care utilization and costs during the first year of life

All-cause (ie, for all conditions, procedures, medications combined) health care utilization and costs were measured from birth hospitalization discharge through the end of the first year of life or end of continuous health plan enrollment, whichever occurred first. The following utilization measures were assessed: hospitalizations in the neonatal period (defined as the time from birth hospitalization discharge to the first 28 days after birth), hospitalizations in the post-neonatal period (defined as >28 days after birth or after birth hospitalization discharge, if infant was discharged after 28 days old, to end of first year of life), emergency department visits, outpatient office visits (including well-baby visits), and outpatient prescriptions measured after discharge from birth hospitalization. Inter-hospital transfers following birth and hospitalizations occurring <2 days after birth discharge were not included. Total costs after birth hospitalization discharge were quantified during the follow-up period by summing the paid amounts on inpatient and outpatient medical claims and outpatient pharmacy claims. Again, costs were adjusted to 2017 US dollars.

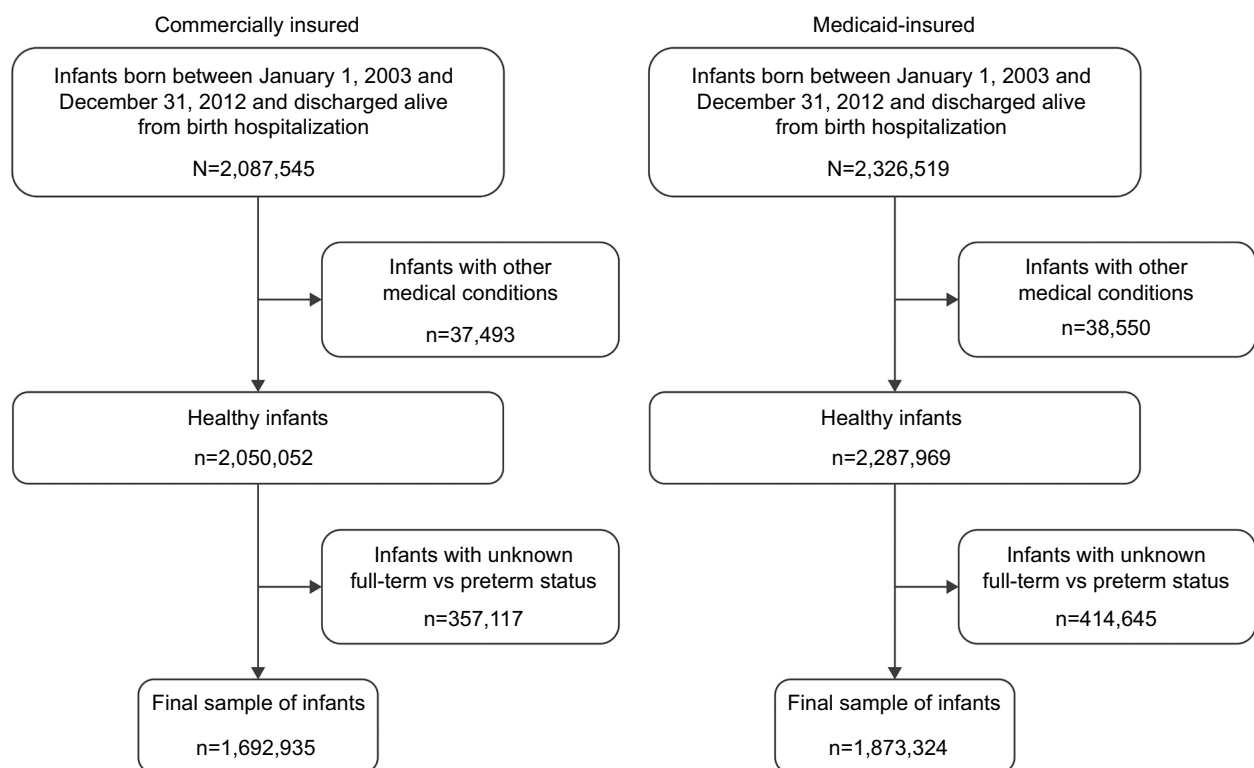
## Analysis

This analysis was descriptive in nature and no statistical comparisons were made. Continuous variables were summarized with means and SDs, whereas categorical variables were summarized with counts and percentages. Summary statistics are presented stratified by preterm and full-term status. Data for commercially insured infants and Medicaid-insured infants were analyzed separately.

## Results

### Study population

Approximately 2.1 million commercially insured infants and 2.3 million Medicaid-insured infants were born from January 1, 2003, to December 31, 2012, and discharged alive (Figure 1). After excluding infants with evidence of the complex medical conditions outlined in the Methods section, gestational age could be determined for 1,692,935 (81.1%) commercially insured infants and 1,873,324 (80.5%) Medicaid-insured infants. Of those infants, 12.5% of commercially insured infants and 13.9% of Medicaid-insured infants were determined to be preterm.



**Figure 1** Infant selection.

Respiratory problems were commonly diagnosed among both commercially and Medicaid-insured early preterm infants, and the prevalence of such conditions increased as gestational age decreased (Table 1). The same was true for other specific comorbid conditions assessed. More than three quarters of infants born at <29 wGA weighed <1,500 g at birth (Figure S1; for reference, the 50<sup>th</sup> percentile birth weight for infants born at <29 wGA is <1,200 g).<sup>8</sup> Birth weight tended to increase as gestational age increased but was often not coded in the claims of older preterm infants.

## Birth hospitalization

Among those with a specific gestational age code, >75% of infants born at <35 wGA were admitted to the NICU regardless of insurance type, and the proportion generally decreased with increasing gestational age (Figure S2). This observation was similar for preterm infants whose gestational age was not specified, as most of those infants were also admitted to the NICU. NICU admission was uncommon for full-term infants without health problems. Overall, the average cost of a birth hospitalization was \$62,931 (SD \$134,347) for

**Table 1** Demographic and clinical characteristics for commercially insured and Medicaid-insured infants

	<29 wGA	29–30 wGA	31–32 wGA	33–34 wGA	35–36 wGA	FT with major health problems	FT without major health problems	Preterm, unknown GA
<b>Commercially insured infants, N</b>	7,653	7,057	14,178	35,240	73,059	187,986	1,293,695	74,067
Male, %	52.6	53.3	53.6	54.1	53.7	55.2	49.9	56.1
<b>Geographic region, %</b>								
Northeast	13.4	14.3	13.7	13.1	14	19.7	16.7	13.5
North Central	23.9	24.9	25.8	27.1	29.1	24.9	29.9	23.1
South	42.4	39.9	38.9	38.7	37.1	37.4	35.8	45.7
West	16.8	17.5	18.4	18.2	16.9	15.3	14.8	15.3
Unknown	3.4	3.4	3.2	3	2.9	2.8	2.8	2.4
<b>Comorbid conditions, %<sup>a</sup></b>								
Intraventricular hemorrhage	17	11.4	6.3	1.3	0.3	0.2	0	1.4
Retinopathy of prematurity	50	44	20.8	3	0.4	0.1	0	6.3
Failure to thrive	4.7	6.8	5.7	4.5	4.1	3.4	2.5	4
Gastrointestinal disease	8.5	4.7	2.4	1	0.4	0.3	0	1.1
Necrotizing enterocolitis	8	4.3	2.1	0.7	0.2	0.14	0	0.8
Respiratory problems	90.2	91.4	81.1	57.5	28	10.4	0.9	51.3
<b>Medicaid-insured infants, N</b>	13,659	10,878	20,513	46,317	97,280	169,129	1,443,022	72,526
<b>Sex, %</b>								
Male	50.4	51.6	51.1	51.7	51.3	53.5	49.6	50.9
Unknown	0.4	0.5	0.3	0.4	0.5	0.4	0.5	0.3
<b>Race/ethnicity, %</b>								
White	28.2	35.6	38.8	42.1	45.4	41.9	48	34.8
Black	31.9	37.3	38.2	35.7	33.4	28.2	28.5	28.3
Hispanic	8.9	9.2	9.8	9.4	8.7	16.3	10.1	23.2
Other/unknown	31	18	13.3	12.8	12.5	13.6	13.5	13.7
<b>Comorbid conditions, %<sup>a</sup></b>								
Intraventricular hemorrhage	20.9	12.4	5.7	1.3	0.3	0.3	0	2.5
Retinopathy of prematurity	45.3	38.2	16.5	2	0.3	0.1	0	7
Failure to thrive	3.4	5.3	5.4	4.8	4.4	3	1.8	3.1
Gastrointestinal disease	10.6	5.6	3.1	1.5	0.8	0.5	0	1.9
Necrotizing enterocolitis	10.2	5.1	2.6	0.9	0.2	0.2	0	1.3
Respiratory problems	90.5	90.4	75.6	49.3	22.7	14.5	1.3	54.2

**Note:** <sup>a</sup>Assessed during period of birth to 3 months old.

**Abbreviations:** FT, full-term; GA, gestational age; wGA, weeks gestational age.

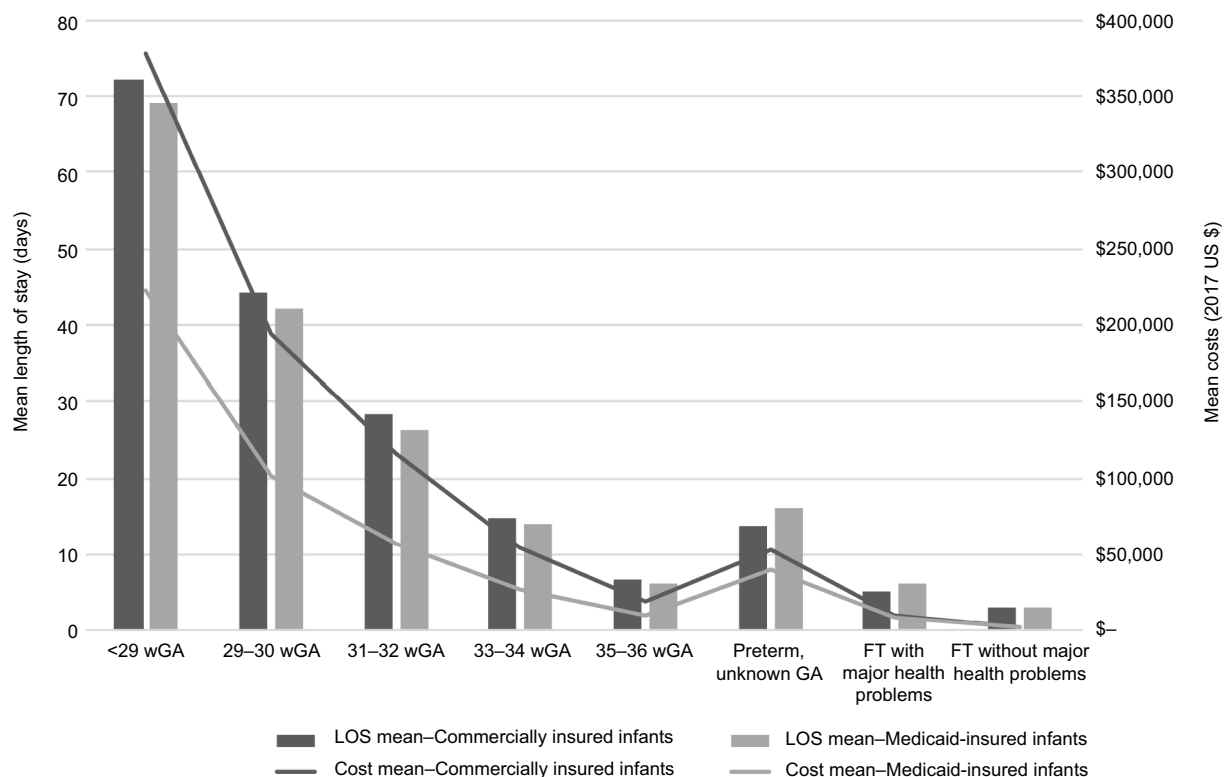
commercially insured preterm infants and \$43,858 (SD \$115,412) for Medicaid-insured preterm infants. Generally, mean LOS and costs increased with decreasing gestational age at birth (Figure 2). Average birth hospitalization LOS and costs were highest among preterm infants born at <29 wGA (LOS: commercial =72.1 days [SD 36.5], Medicaid =69.0 days [SD 38.3]; costs: commercial=\$378,434 [SD \$367,439], Medicaid=\$222,987 [SD \$308,586]) and lowest for full-term infants (LOS: commercial =3.1 days [SD 2.8], Medicaid =3.1 days [SD 2.7]; costs: commercial=\$2,401 [SD \$7,399], Medicaid=\$1,894 [SD \$5,444]). Commercially insured and Medicaid-insured infants had similar birth hospitalization LOS and rates of NICU admissions; however, average costs of birth hospitalizations were lower for Medicaid-insured infants.

### All-cause health care utilization and costs

During the first year of life, 114,364 hospitalizations occurred after birth discharge among commercially insured infants and 207,441 hospitalizations occurred among Medicaid-insured infants. Most of these hospitalizations occurred during the post-neonatal period, defined as >28 days after birth (80,232 of 114,364 hospitalizations [70.2%] among commercially insured infants; 164,558 of 207,441 hospitalizations [79.3%]

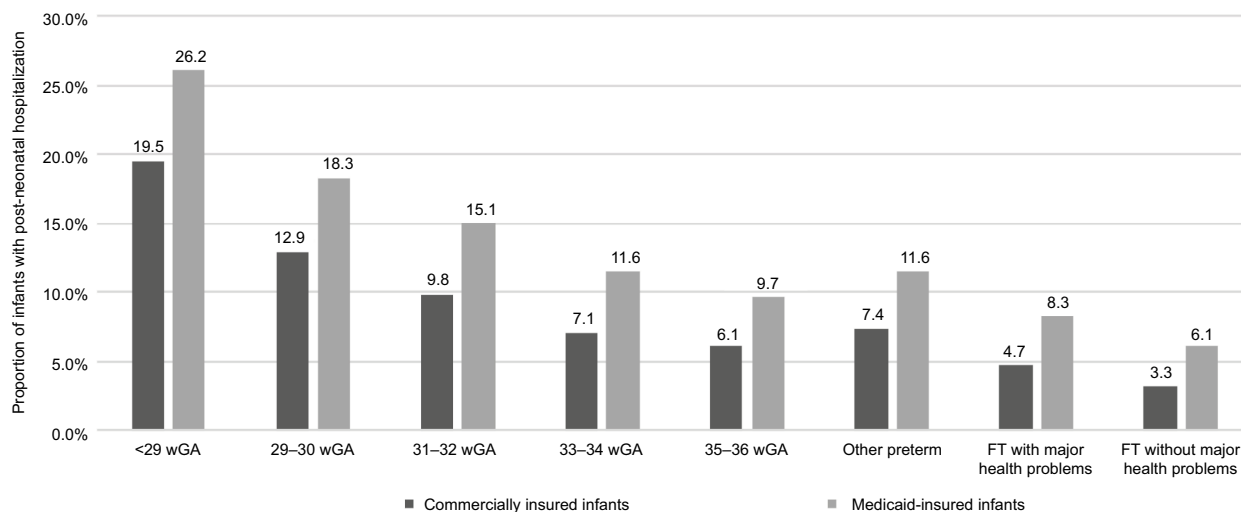
among Medicaid-insured infants). The proportion of infants with a post-neonatal hospitalization was highest among infants born at <29 wGA and decreased as gestational age increased (Figure 3), and for each gestational age group, the proportion of infants hospitalized was greater in Medicaid-insured infants than in commercially insured infants. Using major diagnostic categories, the most common causes of post-neonatal hospitalization across all infant groups were respiratory illness (commercially insured infants: 29.3%–38.4%; Medicaid-insured infants: 32.4%–44.7%) and digestive disease (commercially insured infants: 13.3%–23.8%; Medicaid-insured infants: 12.8%–15.9%).

Like inpatient admissions, emergency department utilization was more common among Medicaid-insured infants (47.1%–53.2%) compared with commercially insured infants (20.3%–28.0%) (Figure 4). However, the differences across gestational age in the proportions of infants with at least one emergency department visit were smaller than the differences in inpatient admission rates. Nearly all infants had at least one outpatient office visit during the first year of life (85.7%–97.6% among commercially insured infants; 86.5%–95.2% among Medicaid-insured infants), including at least one well-baby visit (81.4%–96.1% among commercially insured infants; 78.3%–92.1% among Medicaid-insured

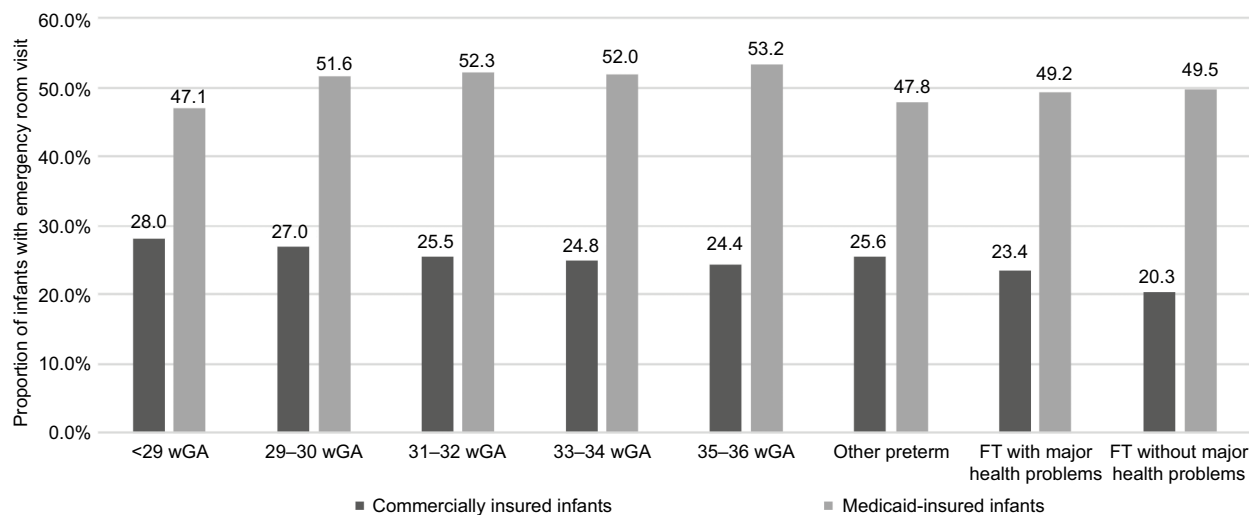


**Figure 2** Birth hospitalization LOS and costs.

**Abbreviations:** FT, full-term; GA, gestational age; LOS, length of stay; wGA, weeks gestational age.



**Figure 3** Proportion of infants with post-neonatal hospitalization.  
**Abbreviations:** FT, full-term; wGA, weeks gestational age.



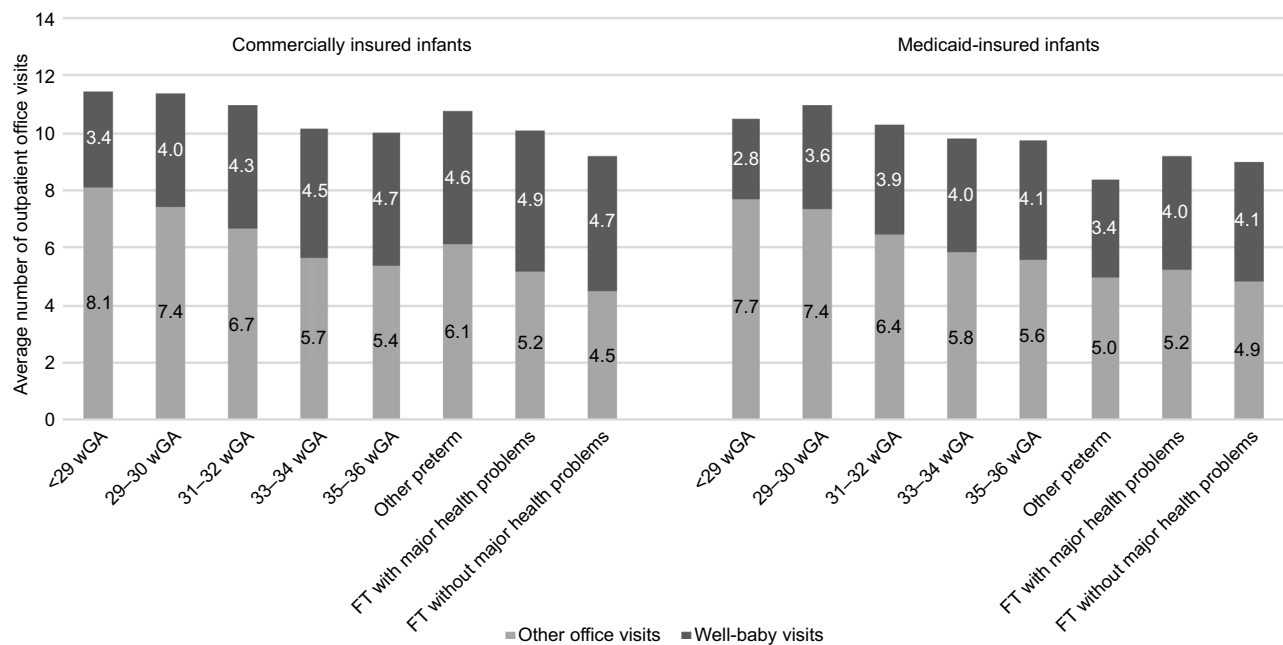
**Figure 4** Proportion of infants with emergency room visit.  
**Abbreviations:** FT, full-term; wGA, weeks gestational age.

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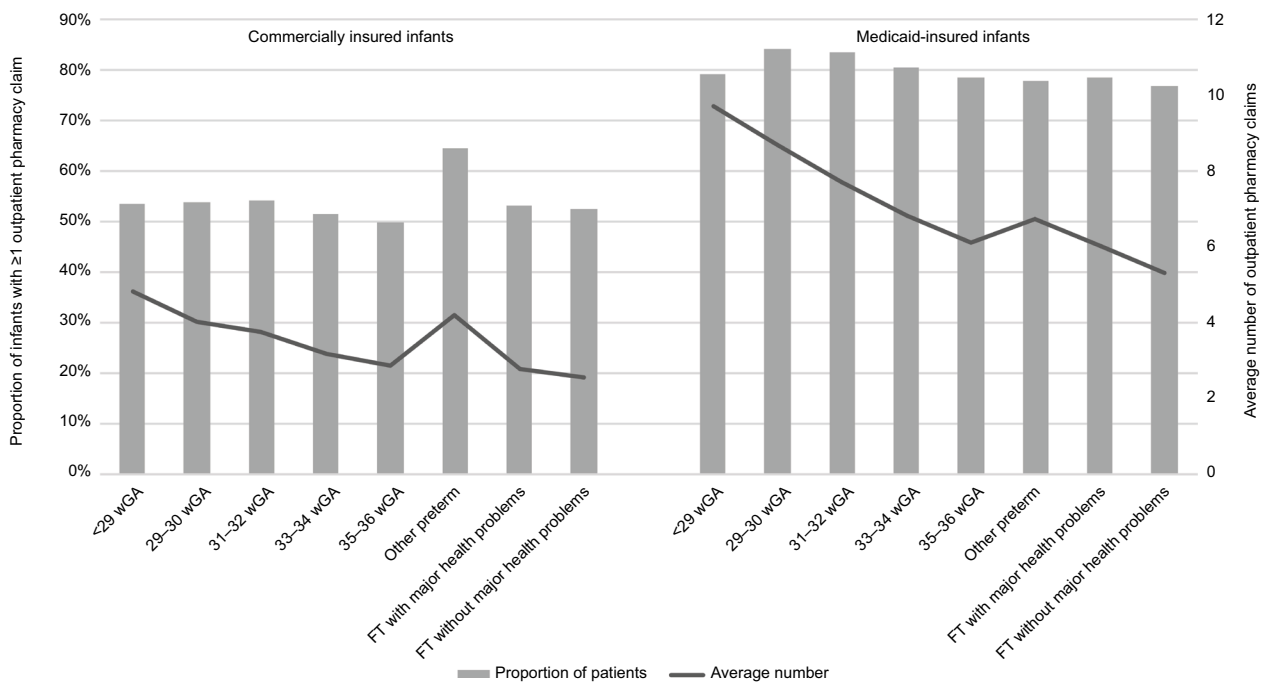
infants). Overall, the average number of office visits was greater among preterm infants compared with full-term infants (Figure 5). The number of visits coded as well-baby visits tended to increase as gestational age at birth increased, whereas the number of visits with other codes decreased (Figure 5). Although similar proportions of preterm and full-term infants had at least one outpatient pharmacy claim, the average number of outpatient pharmacy claim fills decreased with increasing gestational age (Figure 6). The proportion

of infants with at least one outpatient pharmacy claim was smaller among commercially insured infants (~50%) compared with Medicaid-insured infants (~80%).

Following birth discharge, total health care costs per infant per month ranged from \$334 to \$3,126 among commercially insured infants and from \$205 to \$2,473 among Medicaid-insured infants (Figure 7). Costs increased as gestational age at birth decreased. For all gestational age groups, total health care costs were higher among commercially insured infants



**Figure 5** Average number of outpatient office visits.  
**Abbreviations:** FT, full term; wGA, weeks gestational age.

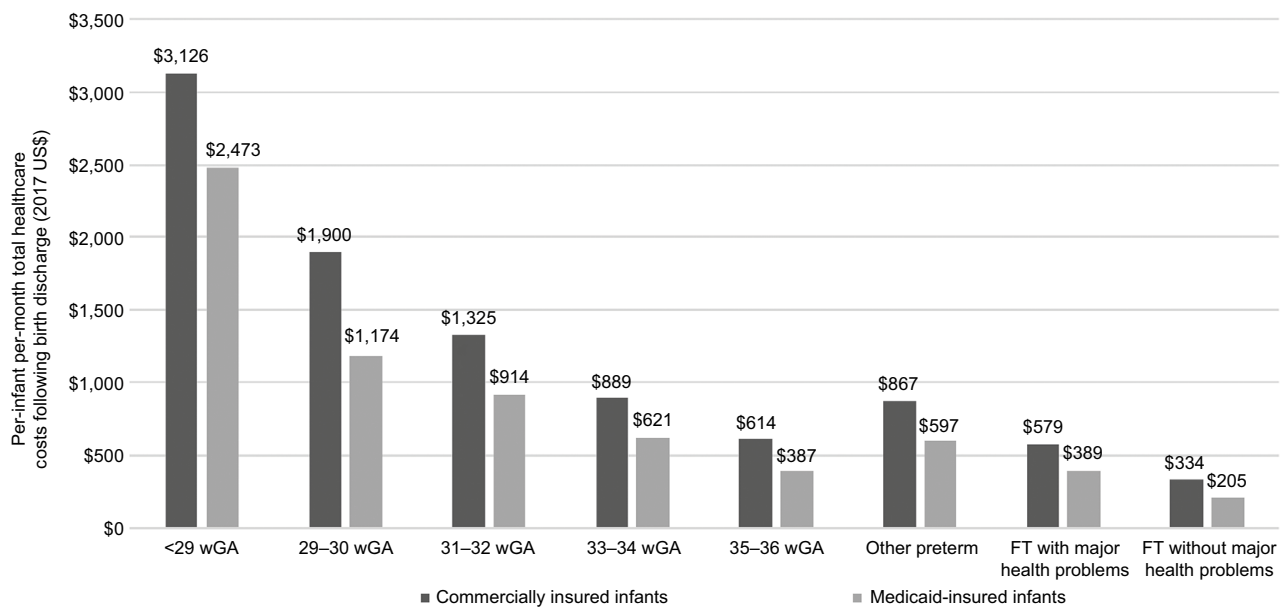


**Figure 6** Outpatient pharmacy utilization.  
**Abbreviations:** FT, full-term; wGA, weeks gestational age.

than among Medicaid-insured infants. For all infant cohorts, the majority of the total costs were for medical services (76%–97%), with the remaining for outpatient pharmacy services. The largest medical services cost contributors for most

cohorts were hospitalization and other outpatient services, with the exception of the commercial full-term cohort without major health problems, where outpatient well baby visits and other outpatient services were the main cost drivers.

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**Figure 7** Per-infant per-month total health care costs (2017 US dollars) following birth discharge. **Abbreviations:** FT, full-term; wGA, weeks gestational age.

## Discussion

This analysis of infants born in the US from 2003 to 2012 indicates that, compared with full-term infants, infants who were born prematurely had longer and more costly birth hospitalizations and also used more health care resources in the first year of life. Birth hospitalization costs and LOS, post-neonatal hospitalization rates, number of outpatient office visits and outpatient pharmacy claims, and total costs all increased as gestational age decreased, with the highest utilization and costs found in infants born at <29 wGA. These trends were present among both commercially insured infants and Medicaid-insured infants.

We found that preterm infants have higher health care utilization and greater health care costs at birth and that costs and utilization increased with decreasing gestational age. These results are consistent with other analyses of preterm and full-term infants that used older data sources and often examined preterm infants as a whole rather than by wGA. Russell et al analyzed hospital discharge data from 2001 and reported that 8% of hospitalizations of infants <1 year old had a diagnosis code of preterm birth or low birth weight, but those hospitalizations accounted for 47% of total hospitalization costs.<sup>7</sup> A March of Dimes study reported that average costs for uncomplicated births were \$4,389, compared to average costs of \$54,149 for premature/low birth weight births.<sup>4</sup> Although these studies provide an important high-level perspective on costs, these summaries obscure

potentially critical differences and trends within the preterm group. One of the few other published studies to acknowledge this potential variability in resource use within the preterm population in the neonatal period was conducted by Phibbs et al and used data from births in California from 1998 to 2000. That study reported that mean costs (and LOS) of neonatal care increased as gestational age at birth decreased using 1-week gestational age groups, and costs ranged (in 2003 US dollars) from \$2,027 (2.6 days) to \$222,563 (78.9 days) among infants born at 37 wGA to infants born at 24 wGA, respectively.<sup>3</sup>

Several analyses have compared birth hospitalizations of early preterm, late preterm, and full-term infants. An analysis of California births from 1993 to 2005 by Ray et al found that median length of birth hospitalization for early preterm infants ( $\leq 33$  wGA) was significantly longer than for late preterm infants (34–36 wGA) and term infants ( $\geq 37$  wGA) (13 vs 2 days).<sup>9</sup> Although the study by Ray et al reported that median LOS was the same for late preterm and full-term infants,<sup>9</sup> a study by McLaurin et al using the MarketScan commercial data from 2004 found that birth hospitalizations of late preterm infants (33–36 wGA) were longer and more expensive than hospitalizations of term infants (mean LOS = 8.8 vs 2.2 days; mean costs = \$26,054 vs \$2,087; median costs = \$11,006 vs \$1,176).<sup>5</sup> Differences in costs and LOS during birth hospitalization may be due to differences in medical complications. For example, Bird et al found that



infants born at 34–36 wGA had significantly longer birth hospitalizations, as well as greater odds of mechanical ventilation, respiratory distress syndrome, apnea, and hypoglycemia during birth hospitalization compared to infants born at 37–42 wGA in a study of Arkansas Medicaid enrollees born between 2001 and 2005.<sup>6</sup>

Hospitalization during the first year of life is a particularly important outcome from both clinical and economic perspectives. We found that the proportion of infants with a post-natal hospitalization was substantially higher for preterm infants than for full-term infants and the hospitalized proportion decreased with increasing gestational age. Older studies have reported similar results. A California-based study by Underwood et al analyzing infants born from 1992 to 2000 reported that the proportion of infants with evidence of rehospitalization during the first year of life ranged from 31% among infants born <25 wGA to 13% among infants born at 36 wGA.<sup>10</sup> Ray et al also found that from birth hospitalization discharge to the end of the first year of life, 16.0% of early preterm infants ( $\leq 33$  wGA), 12.5% of late preterm infants (34–36 wGA), and 9.5% of term infants had a rehospitalization.<sup>9</sup> Using infants born at 40 wGA as the reference group, infants born at 23 wGA experienced greater than three times increased odds for any rehospitalization compared with 40 wGA.<sup>9</sup> When comparing late preterm (33–36 wGA) and full-term infants in the MarketScan data, McLaurin et al found that late preterm infants were nearly twice as likely to be rehospitalized during the first year of life (15.2% vs 7.9%) overall and were nearly twice as likely to be rehospitalized at least 15 days after discharge from birth hospitalization (12.1% vs 6.8%).<sup>5</sup> The costs of rehospitalizations were also higher for late preterm compared to full-term infants (mean = \$15,591 vs \$8,914; median = \$5,815 vs \$4,010).<sup>5</sup> Trends in rehospitalizations during the neonatal period are difficult to describe across gestational age because many preterm infants have not been discharged from their birth hospitalization by 28 days old.<sup>5</sup>

In our study, differences in utilization across gestational age groups were most apparent in the proportions of infants with post-neonatal hospitalizations for which a downward trend was observed for both commercially insured and Medicaid-insured infants. The proportion of infants with emergency department visits was more varied across gestational age groups but trended toward small decreases with increasing gestational age for commercially insured infants. By contrast, the proportion with emergency department visits in the Medicaid population was higher for infants 29–30 wGA than for those <29 wGA but stayed fairly stable across

the remaining preterm gestational age groups. The trend in per-infant-per-month costs was similar to that observed for inpatient utilization, where the largest decreases in both the commercially insured and Medicaid infants occurred between the <29 wGA group and the 29–30 wGA group.

The pattern of visits for well-baby care suggests that preterm infants and Medicaid-insured infants are less likely than full-term and commercially insured infants to have physician encounters solely for preventive care. Specifically, preterm infants had a greater proportion of office visits coded as “other” relative to well-baby care, suggesting they receive additional services during regularly scheduled visits. The average number of well-baby visits increased with gestational age, although even among full-term infants without major health problems, there were fewer visits than the number recommended in the 2014 American Academy of Pediatrics Recommendations for Preventive Pediatric Health Care guidelines, which normally recommend visits at 3–5 days old, 1 month, 2 months, 4 month, 6 months, 9 months, and 12 months of age.<sup>11</sup> However, visit schedules may differ by circumstances,<sup>11</sup> and it is possible that some visits initially undertaken as well-baby visits were coded with other diagnoses as clinical findings were obtained during the visits or that well-baby procedures were performed at visits initiated to address existing or incidental conditions or symptoms.

Increased health care utilization translates into higher costs during the first year of life. We found that total all-cause monthly costs during the first year of life were nine times higher and 12 times higher for commercially insured and Medicaid-insured infants born at <29 wGA vs full-term infants without major health problems, respectively. Another study that used the MarketScan to examine commercially insured infants born in 2004 found that late preterm infants (33–36 wGA) had greater total costs during the first year of life (excluding birth hospitalization) than full-term infants (mean = \$12,247 vs \$4,069; median = \$4,733 vs \$2,389), with higher costs for all service types, ranging from hospitalizations to prescription drugs,<sup>5</sup> a finding also shown in the current study.

Our analysis included both commercially insured and Medicaid-insured infants. We found that infants from commercially insured and Medicaid-insured populations have similar birth hospitalization experiences in terms of LOS and admission to the NICU. Birth hospitalization costs were higher for commercially insured infants, likely due to differences in reimbursement rates between the payers. The similarities in birth characteristics in these populations contrast with the health care resource use differences noted in the first year of life. Although in both payer populations,

health care utilization and costs trended downward as gestational age increased, Medicaid-insured infants used more health care resources compared to commercially insured infants, for all preterm and full-term subgroups. The most notable differences were the proportion of infants receiving emergency room and inpatient and outpatient pharmacy services. Barradas et al also reported differences in hospitalizations by payer among preterm/low birth weight infants using the National Inpatient Sample in 2009.<sup>2</sup> They found that among preterm/low birth weight infants, rehospitalization was more common for Medicaid-insured infants compared to commercially insured infants (7.6% vs 4.3%), as were neonatal hospitalization transfers after birth (7.3% vs 6.5%).<sup>2</sup> Barradas et al hypothesize that higher rehospitalization rates may reflect lack of effective primary care provided to Medicaid-insured infants.<sup>2</sup> This explanation is also plausible for our findings of greater use of emergency room visits as well; however, it would not explain the greater number of pharmacy claims noted in the Medicaid population. Other potential explanations include other pathways (eg, nutrition, home environment, pathogen exposure) through which lower socioeconomic status has a negative impact on health.

In our study sample, 12.5% of commercially insured infants and 13.9% of Medicaid-insured infants were coded as preterm. These numbers are slightly higher than the 9.57% reported by the Centers for Disease Control and Prevention (CDC) for 2014 US births.<sup>1</sup> This is most likely due to our exclusion of infants with unknown gestational age from our patient sample. When we divide the number of premature infants by total births, the proportion is more consistent with the CDC report (10% for commercially insured infants and 11% for Medicaid-insured infants).

Premature birth has serious implications, including increased rates of post-neonatal hospitalization and higher health care utilization in the first year of life. We found that the most common causes of post-neonatal hospitalization were respiratory and digestive issues. Preterm infants are at an increased risk for respiratory morbidity due to small lung volumes, reduced lung surface area, smaller airways, and an increased air space wall thickness.<sup>12,13</sup> Preterm birth also disrupts the normal development of the gastrointestinal tract.<sup>14</sup> Intestinal muscles needed for coordinated contractions may be underdeveloped,<sup>15</sup> the gastrointestinal tract may be shorter, and the lower esophageal sphincter tone may be decreased in preterm infants compared to full-term infants.<sup>14</sup> In addition, preterm birth can disturb the normal development of the neonatal intestinal microbiota due to delayed enteral nutrition, antibiotic use, and instrumentation,<sup>16,17</sup> with

serious consequences such as necrotizing enterocolitis.<sup>17-19</sup> Longer-term analyses have also found that increased risk for hospitalization persists into childhood and adolescence for children born prematurely compared to those born full-term.<sup>20,21</sup> More research on health care utilization in preterm infants may inform strategies to reduce the high rates of post-neonatal hospitalization and other consequences.

This analysis has limitations. Administrative claims are generated for billing purposes, not research. Full-term and preterm status and comorbidities were identified through the presence of DRG and/or ICD-9-CM diagnosis codes; therefore, misclassification may have occurred due to coding errors or under-/over-coding. Similarly, the proportion of infants admitted to the NICU and the number of office visits coded as well-baby visits may be underestimated because of coding inconsistencies. However, we do not believe that coding inconsistencies could account for the differences found in this study, specifically for NICU admissions, in which similar trends have been reported elsewhere.<sup>22</sup> Some infants included in the sample were not followed for a full year after birth because they were disenrolled in the database due to, for example, the beneficiary on their policy, presumably a parent, leaving the insurer that contributes to the MarketScan database. For these infants, utilization and costs would be underestimated. Infants who died after birth discharge would also appear to have disenrolled. However, in this study, over 80% of infants were enrolled through the first year of life. We do not know the level of Medicaid coverage and how it varies across plans and states. We also acknowledge that the Medicaid data do not represent all US states and, therefore, results may not generalize to the nation as a whole.

## Conclusion

Infants born prematurely have longer and costlier birth hospitalizations than full-term infants, and resource use increased with lower gestational age at birth. During the first year of life, health care utilization among Medicaid-insured infants was greater than that among commercially insured infants. Notably, differences in costs and utilization between preterm and full-term infants observed during the birth hospitalization persist through the first year of life, with post-neonatal hospitalization rates, number of outpatient office visits and outpatient pharmacy claims, and total all-cause monthly costs increasing with decreasing gestational age.

## Data sharing statement

The data used for this analysis were from proprietary databases and could not be made publicly available due to

agreements between Truven Health Analytics and the data contributors. More information about the data can be obtained by contacting the corresponding author.

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## Disclosure

Kimmie K McLaurin and Ifedapo R Olajide are employees of AstraZeneca. Amanda M Kong and David Diakun are employees of IBM Watson Health, which was contracted by AstraZeneca for data analyses. Sally W Wade is a consultant to IBM Watson Health. Jane Germano has nothing to disclose. The authors report no other conflicts of interest in this work.

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