Epidemiology of Surgical Procedures, Anesthesia, and Imaging Studies by Gestational Age during the First Year of Life in Medicaid-Insured Infants

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Objectives To evaluate the rate of surgical procedures, anesthetic use, and imaging studies by prematurity status for the first year of life we analyzed data for Texas Medicaid-insured newborns.

Study design We developed a retrospective population-based live birth cohort of newborn infants insured by Texas Medicaid in 2010-2014 with 4 subcohorts: extremely premature, very premature, moderate/late premature, and term.

Results In 1 102 958 infants, surgical procedures per 100 infants were 135.9 for extremely premature, 35.4 for very premature, 15.5 for moderate/late premature, and 6.5 for term. Anesthetic use was 62.0 for extremely premature, 20.8 for very premature, 11.1 for moderate/late premature, and 5.6 for the term subcohort. The most common procedures in the extremely premature were neurosurgery, intubations, and procedures that facilitated caloric intake (gastrostomy tubes and fundoplications). The annual rates for the first year of life for chest radiograph ranged from 15.0 per year for the extremely premature cohort to 0.6 for term infants and for magnetic resonance imaging (MRI) from 0.3 to 0.01. MRI was the most common imaging study with anesthesia support in all maturity levels. MRIs were done in extremely premature without anesthesia in over 90% and in term infants in 57.2%.

Conclusions Surgical procedures, anesthetic use, and imaging studies in infants are common and more frequent with higher a degree of prematurity while the use of anesthesia is lower in more premature newborns. These findings can provide direction for outcome studies of surgery and anesthesia exposure. *(J Pediatr 2021;229:147-53)*.

Health care during the first year of life is an important determinant of the well-being of children and adults with medical care needs driven by birth outcomes, such as prematurity, congenital anomalies, susceptibility to infection, and adverse social environments. Studies of health care use during this period have generally focused on neonatal intensive care, hospital admissions, and preventive services.[1,2] Surgical procedures are important medical events, both as an indicator of illness and of exposure to iatrogenic risks, but little is known about the population-level use of surgical and anesthetic services in infancy.

Although there are some previous reports on use of perioperative services, these studies only include in- or outpatient procedures, do not focus on infants or only track subsets of children or procedures.[3-6] Because of these limitations, the overall rates of surgery and anesthetics are underestimated or unavailable. As an example, at the Children's Hospital at Dartmouth, a tertiary care center for children in New England, 66% of all anesthetic care for children under age 1 is provided to outpatients (internal, unpublished data for 2018, provided by Kristin E. Charette, QA Project Manager, Department of Anesthesiology, Dartmouth Hitchcock Medical Center, Lebanon, NH on July 3rd, 2019). Furthermore, no studies have reported use of these services by prematurity status.

To fill this knowledge gap, we report the use of anesthetic and surgical procedures for the entire and diverse population of Texas Medicaid-insured children <1 year of age by linking Medicaid-insured infant use with natality and maternity files. We also report imaging studies because these are common in infants who undergo a procedure and, in some instances, imaging studies require anesthesia. The incidence rates of the exposure of newborns and infants to surgery and anesthesia are foundational to planning clinical care and to outcome research on associated benefits and risks.

CPT	Current Procedural Terminology
ENT	Otorhinolaryngology
KUB	Kidney, ureter, and bladder
MRI	magnetic resonance imaging

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Methods

We developed a retrospective cohort of infants insured by Medicaid and born in Texas from January 1, 2010, to December 31, 2014, and followed for a full year of life, through linking Texas Department of State Health Services natality records with newborn (92.8% link rate) and maternal (88%) Medicaid enrollment records. Medicaid insured 54% of all Texas births in 2014, and newborn infants receive care in >250 hospitals and 150 neonatal intensive care units (2010-2014).[7] These linked records were then joined to maternal and newborn facility and professional claims and encounters.

Cohort

The original cohort had 1 133 441 infants; 310 infants were excluded because of birth weight less than 500 grams and 30 173 because they were not Medicaid enrolled in the first 30 days of life after birth. The final cohort consisted of 1 102 958 infants. Four infant subcohorts were defined that indicate degrees of prematurity: (1) extremely premature, ≤28 weeks gestational age, (2) very premature, >28 to ≤32 weeks gestational age, (3) moderately/late premature, >32 to <37 weeks, and (4) term, ≥37 weeks gestational age. If gestational age was missing, the infant was not included in the analysis. The subcohorts consisted of 8611 (0.8%) extremely premature, 15 336 (1.4%) very premature, 96 484 (8.7%) moderate/late premature, and 982 527 (89.1%) term newborns. Birth weight was divided into 4 groups: (1) 500-1499 g, (2) 1500-2499 g, (3) 2500-3999 g, and (4) ≥4000 g. Infants with a birth weight of <500 g were excluded from all analyses. To provide rates of occurrence over time, the first year was divided into the first 30 days of life (n = 1 102 958), days 31-180 (1 066 519), and days 181-365 (1 023 356). To be eligible for inclusion, an infant had to be enrolled in the same month as the birth month. If an infant was enrolled in months 0-6, they were included in the 31-180 day cohort. If there was any gap in enrollment, the infant was excluded. Because there is fluctuation in Medicaid enrollment, the denominator for these time periods decreased slightly across these time periods.

Surgery, Anesthesia, and Imaging Studies Current Procedural Terminology Grouping

For surgical procedures, Current Procedural Terminology (CPT) codes were summarized by groups of procedures (**Appendix**; available at www.jpeds.com). As an example, within pediatric general surgery, a group called "abdominal wall defects" was defined, consisting of CPT codes 49600, 49605, and 49606 (omphalocele—small, primary closure; gastroschisis/omphalocele [large] with or without a prosthesis; removal silo—final closure). Circumcisions were excluded from the analysis. Anesthetics for surgical procedures were divided by subspecialty (pediatric general surgery, pediatric urology, pediatric otorhinolaryngology [ENT], pediatric cardiac surgery, pediatric plastic surgery, pediatric neurosurgery, pediatric orthopedic surgery, cardiology, etc).

Calculation of Rates

Rates were calculated as events per 100 infants with 95% CIs to indicate population-level use. For example, if an individual infant had 5 operations within the first year of life and 99 children had none, the rate was 5 per 100. Similarly, if an infant had 2 events on the same day, then these were counted separately. As a final example, if a newborn had an magnetic resonance imaging (MRI) in the morning with anesthesia, followed by a central line placement with no associated anesthesia CPT code, and then subsequent brain surgery on the same day; we counted 2 surgical events (line and brain surgery), 2 anesthesia events (associated with MRI and brain surgery), and 1 imaging event. For imaging studies with anesthetic care, a specific code for anesthesia with radiologic procedures (CPT 01922) was associated with the billing code for the imaging study. If the anesthesia claim was missing, the imaging event was counted as without anesthesia.

The project was approved by the Institutional Review Boards of Dartmouth College, the University of Texas Health Science Center (Houston), and the Texas Health and Human Services Commission (Austin).

Results

Demographic Data

The overall cohort included 1 102 958 infants, born and enrolled in Texas Medicaid between January 1, 2010, and December 31, 2014. Cohort characteristics are presented in **Table I**. Excluding circumcisions, infants with procedures were more likely to be male (51.2%) and with lower birthweight and gestational age. Their mothers were more likely to be non-Hispanic and to have higher levels of educational attainment. Of all procedures, 5.7% were performed in extremely premature infants, 4.4% in very premature infants, 13.0% in moderately/late premature, and 77.0% in term infants.

Surgical Procedures in the First Year of Life

The overall rate of surgical procedures was 8.7 per 100 within the first year of life. Among extremely premature infants, the rate was 135.9 per 100, for very premature 35.4, for moderate/late premature 15.5, and for term 6.5. More detailed event rates for the time periods 0-30, 31-180, and 181-365 days is available in **Table II**.

Type of Procedures in the First Year of Life

The 3 most common procedure groups for children under age 1 for extremely premature infants were neurosurgical procedures (32.4 per 100), intubations (21.1), and gastrostomy tubes (10.6). For very premature infants, the most common were intubations (7.7), vascular access (2.9),

Table I. Cohort and maternal demographics

Cohort characteristics	Overall (n = 1 102 958) No.	%	With procedure (n = 73 457) No.	%	Without procedure (n = 1 029 501) No.	%
Sex						
Female	538 700	48.8	27 049	36.8	511 651	49.7
Male	565 258	51.2	46 408	63.2	517 850	50.3
Birth weight (g)						
500-1499	14 408	1.3	5738	7.8	8670	0.8
1500-2499	82 369	7.5	9063	12.3	73 306	7.1
2500-3999	943 913	85.6	54 310	73.9	889 603	86.4
>4000	61 841	5.6	4179	5.7	57 662	5.6
Unknown	427	0	167	0.2	260	0
Gestational age (weeks)						
≤28	8611	0.8	4190	5.7	4421	0.4
28 to ≤32	15 336	1.4	3220	4.4	12 116	1.2
32 to <37	96 484	8.8	9520	13.0	86 964	8.5
≥37	982 527	89.1	56 527	77.0	926 000	90.0
Plurality						
Single	1 075 146	97.5	70 258	95.7	1 004 888	97.6
Multiple	27 803	2.5	3199	4.4	24 604	2.4
Unknown	9	0	0	0	9	0
Maternal characteristics	**Overall (n = 1 102 958) No.**	**%**	**With procedure (73 457) No.**	**%**	**Without procedure (1 029 501) No.**	**%**
Race						
Black	156 081	14.2	11 495	15.7	144 586	14.0
Non-black	944 117	85.6	61 830	84.2	882 287	85.7
Unknown	2760	0.3	132	0.2	2628	0.3
Ethnicity						
Hispanic	676 422	61.3	38 940	53.0	637 482	61.9
Non-Hispanic	424 268	38.5	34 396	46.8	389 872	37.9
Unknown	2268	0.2	121	0.2	2147	0.2
Maternal age (y)						
≤19	179 538	16.3	11 404	15.5	168 134	16.3
20-24	380 964	34.5	25 055	34.1	355 909	34.6
25-29	282 244	25.6	18 952	25.8	263 292	25.6
30-34	167 565	15.2	11 491	15.6	156 074	15.2
35-40	74 545	6.8	5199	7.1	69 346	6.7
≥40	18 101	1.6	1356	1.9	16 745	1.6
Unknown	1	0.0	0	0	1	0
Maternal education level						
No high school degree	372 360	33.8	21 805	29.7	350 555	34.1
High school degree or General Educational Development	392 022	35.5	26 621	36.2	365 401	35.5
Some college	288 664	26.2	21 339	29.1	267 325	26.0
College degree or more	49 912	4.5	3692	5.0	46 220	4.5
Parity						
Primiparous	403 597	36.6	28 346	38.6	375 251	36.5
Multiparous	699 161	63.4	45 095	61.4	654 066	63.5
Unknown	200	0	16	0	184	0

and inguinal hernia repairs (2.9). For moderate/late premature children, the order was vascular access at 1.7 per 100, intubations (1.5), and ENT endoscopies (1.3). In term children, ear tubes were most common at a rate of 1.0 per 100, ENT endoscopies (0.7), and vascular access procedures (0.5). More detailed information is available in **Table III** and **Table IV** (available at www.jpeds.com). The rates of surgery and anesthesia by prematurity annualized by time periods within the infancy are displayed in the **Figure**. The annualized rate of anesthesia and surgery declines over the course of the first year of life and use is highest in the extremely premature group. This effect is more pronounced for surgical procedures than it is for anesthesia.

Anesthesia in the First Year of Life

The rate of anesthetics for the overall cohort was 6.7 per 100 and was 61.9 per 100 for extremely premature, for very premature 20.8, for moderate/late premature 11.1, and for term 5.5.

The 3 most common reasons for an anesthetic, excluding imaging studies that are presented below, in the extremely premature group were general surgical procedures (29.4 per 100), interventional or diagnostic heart catheterization and other cardiology procedures (9.5), and neurosurgical procedures, for example, shunts (6.3). For very premature infants, the 3 most common were general surgical procedures (9.5), interventional radiology (3.3), and ENT (2.7) procedures. In the moderate/late premature infants, the rate of

Table II. Counts and rates of anesthesia and procedure events by degree of prematurity in the first year of life (multiple events per day included)

Degrees of prematurity	0-365 Days (n = 1 102 958)		0-30 Days (n = 1 102 958)		31-180 Days (n = 1 066 519)		181-365 Days (n = 1 023 356)	
	Event count*	Rate per 100 (95% CI)	Event count*	Rate per 100 (95% CI)	Event count*	Rate per 100 (95% CI)	Event count*	Rate per 100 (95% CI)
Extremely preterm (≤28 w)	(n = 8611)		(n = 8611)		(n = 7205)		(n = 6597)	
Anesthetics	5333	62.0 (60.3-63.6)	1061	12.3 (11.6-13.1)	2750	38.2 (36.7-39.6)	1179	17.9 (16.9-18.9)
Procedures	11 700	135.9 (133.4-138.3)	3350	38.9 (37.6-40.2)	6062	84.1 (82.0-86.2)	1673	25.4 (24.1-26.6)
Very preterm (28-≤32 w)	(n = 15 336)		(n = 15 336)		(n = 14 502)		(n = 13 767)	
Anesthetics	3192	20.8 (20.1-21.5)	471	3.1 (2.8-3.3)	1488	10.3 (9.7-10.8)	1099	8.0 (7.5-8.5)
Procedures	5435	35.4 (34.4-36.3)	1830	11.9 (11.4-12.5)	2198	15.2 (14.5-15.8)	1170	8.5 (8.0-9.0)
Moderately preterm (32-<37 w)	(n = 96 484)		(n = 96 484)		(n = 92 920)		(n = 88 837)	
Anesthetics	10 661	11.1 (10.8-11.3)	1916	2.0 (1.9-2.0)	3917	4.2 (4.1-4.4)	4431	5.0 (4.8-5.1)
Procedures	14 977	15.5 (15.3-15.8)	4614	4.8 (4.6-4.9)	5593	6.0 (5.9-6.2)	4204	4.7 (4.6-4.9)
Term (≥37 w)	(n = 982 527)		(n = 982 527)		(n = 951 892)		(n = 914 155)	
Anesthetics	54 579	5.6 (5.5-5.6)	6661	0.7 (0.7-0.7)	17 729	1.9 (1.8-1.9)	28 805	3.2 (3.1-3.2)
Procedures	64 284	6.5 (6.5-6.6)	14 888	1.5 (1.5-1.5)	21 605	2.3 (2.2-2.3)	25 741	2.8 (2.8-2.9)

anesthesia was 3.8 per 100 for general surgery, 2.0 procedures for radiology, and 1.9 for ENT. In term infants, anesthesia for ENT procedures were most common at a rate of 1.4 per 100 followed by general surgery (1.2) and imaging studies requiring anesthesia (1.0).

Table III. Three most common procedure types for requiring anesthesia and 3 most common procedure categories for infants (excludes imaging studies)

Procedure types	0-365 Days (n = 1 102 958)		
	Description	Event days	Rate per 100 (95% CI)
Extreme preterm (≤28 w)	(n = 8611)		
Anesthetics	Pediatric surgery	2530	29.4 (28.2-30.5)
	Cardiology	821	9.5 (8.9-10.2)
	Neurosurgery	544	6.3 (5.8-6.9)
Procedures	Neurosurgery	2791	32.4 (31.2-33.6)
	Intubations	1820	21.1 (20.2-22.1)
	Gastrostomy tubes - fundoplications	914	10.6 (9.9-11.3)
Very preterm (28-≤32 w)	(n = 15 336)		
Anesthetics	Pediatric surgery	1458	9.5 (9.0-10.0)
	Radiology	511	3.33 (3.0-3.6)
	ENT	417	2.7 (2.5-3.0)
Procedures	Intubations	1183	7.7 (7.3-8.1)
	Access	453	3.0 (2.7-3.2)
	Inguinal hernia repair	450	2.9 (2.7-3.2)
Preterm (32-<37 w)	(n = 96 484)		
Anesthetics	Pediatric surgery	3685	3.8 (3.7-3.9)
	Radiology	1892	2.0 (1.9-2.1)
	ENT	1811	1.9 (1.0-2.0)
Procedures	Access	1662	1.7 (1.6-1.8)
	Intubations	1440	1.5 (1.4-1.6)
	Scopes	1264	1.3 (1.2-1.4)
Term (≥37 w)	(n = 982 527)		
Anesthetics	ENT	13 579	1.4 (1.4-1.4)
	Pediatric surgery	11 549	1.2 (1.2-1.2)
	Radiology	10 006	1.0 (1.0-1.0)
Procedures	Ear tubes	10 074	1.0 (1.0-1.1)
	Scopes	6514	0.7 (0.7-0.7)
	Access	4811	0.5 (0.5-0.5)

Imaging Studies in the First Year of Life

The most common imaging study without anesthesia in extremely premature children was chest radiograph at a rate of 1504 per 100 followed by abdominal radiograph (kidney, ureter, and bladder [KUB]) at 845 and head ultrasound examination, 264. MRIs without anesthesia were done in 29.8 per 100 and with anesthesia in 2.7 or 8.4% of all MRIs in the extremely premature group. The same order of rates was found for very premature infants, the rate for chest radiograph was 397, KUB at 220, and head ultrasound examination, 108. The rate of MRIs without anesthesia was 8.6 and with, 2.1, or 19.4% of all MRIs. In moderate/late premature children, chest radiographs were done at a rate of 140 per 100, KUBs at 48, and head ultrasound examinations, 12. The rate of MRIs without anesthesia was 2.3 and with 1.2, 35.3%. Finally, for term infants, chest radiograph were done at a rate of 58 per 100, KUB, 12 and head ultrasound examinations, 2.0. MRIs in term children were done in 0.8 without and in 0.6 per 100 with anesthesia (42.8%). More detailed information on MRIs with and without anesthesia is available in Table V.

Discussion

Surgical procedures and anesthetics are common in Texas Medicaid-insured infants, increase with the degree of prematurity, and decline during the first year of life. Extremely premature infants have, on average, 1.4 procedures and 0.6 anesthetics in their first year of life, and 32.5% have an MRI. Exposure to anesthesia ranges from 5 per 100 for term to 62 per 100 for extremely premature infants in the first year of life with an average of 6.7 per 100 for all. The rate at which MRIs are done in conjunction with anesthesia is

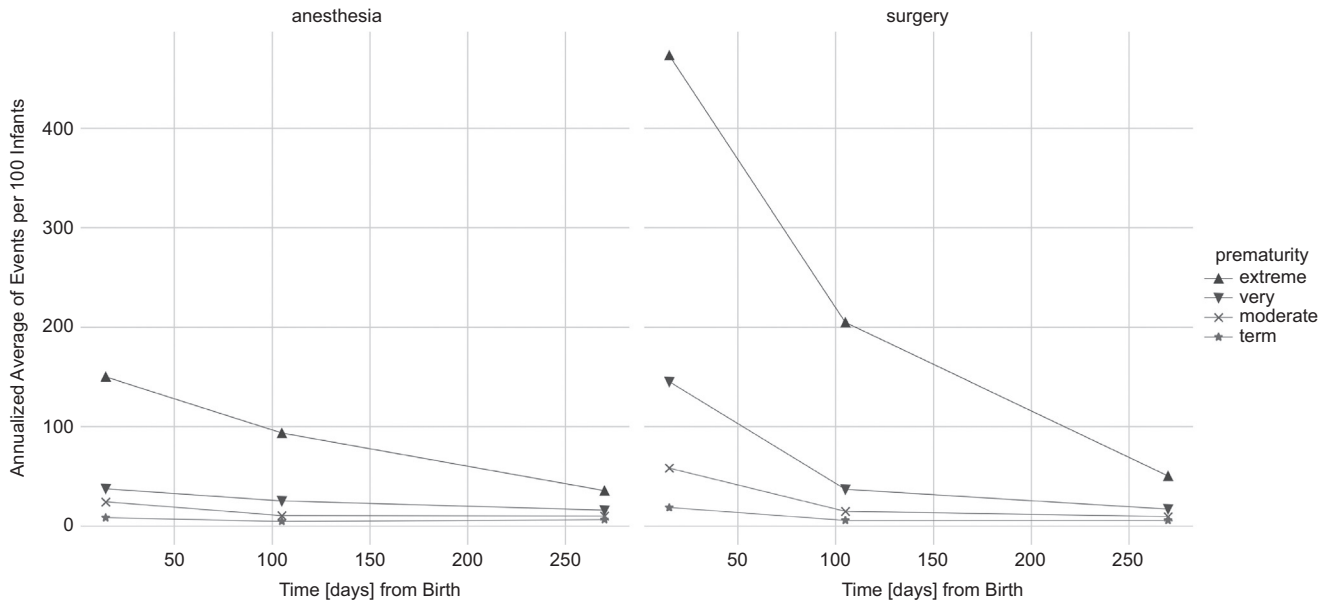

Figure. Annualized rate of anesthesia and surgery in events per 100 infants of life for days 0-30, 30-180, and 181-365 by degree of prematurity.

inversely related to the degree of prematurity and increases over time during the first year of life. Many imaging studies without anesthesia in preterm babies were likely done during hospitalization after birth.

Estimates of the rate at which children undergo surgical procedures and are exposed to anesthesia are difficult to estimate in the US owing to the absence of a national all claims payer dataset. Given the high proportions of births insured by Medicaid, its claims data are a useful alternative for population-based maternal and child health research.[7,8]

Previous studies demonstrate the usefulness of measuring pediatric surgical care. A study from the UK, for example, used population-based data to identify surgical outcome outliers for directing efforts to improve care.[9] A second UK analysis recommended that practitioners should not "undertake occasional paediatric practice."[10] Subsequently, the perioperative care of children changed toward specialized centers.[11] In the US, the Kid's Inpatient Database has been used to determine that 40% of all pediatric operations are performed in adult hospitals.[5] In contrast, in infants with very low birth weight undergoing surgical procedures, although 6.8% had neither a pediatric surgeon or anesthesiologist, 85.8% were under the care of both subspecialists.[6] Medicaid data from California

Table V. MRIs within the first year of life with or without anesthesia

		0-365 Days (n = 1 102 958)		0-30 Days (n = 1 102 958)		31-180 Days (n = 1 066 519)		181-365 Days (n = 1 023 356)	
Maturities	**Anesthesia**	**Event days**	**Rate per 100 (95% CI)**	**Event days**	**Rate per 100 (95% CI)**	**Event days**	**Rate per 100 (95% CI)**	**Event days**	**Rate per 100 (95% CI)**
Extreme preterm (≤28 w)		(n = 8611)		(n = 8611)		(n = 7205)		(n = 6597)	
	Yes	237	2.8 (2.4-3.1)	1	0.01 (0.0-0.03)	66	0.9 (0.7-1.1)	157	2.4 (2.0-2.8)
	No	2569	29.8 (28.7-31.0)	47	0.6 (0.4-0.7)	2131	29.6 (28.3-30.8)	247	3.7 (3.3-4.2)
Very preterm (28-≤32 w)		(n = 15 336)		(n = 15 336)		(n = 14 502)		(n = 13 767)	
	Yes	326	2.1 (1.9-2.4)	8	0.05 (0.02-0.09)	123	0.9 (0.7-1.0)	185	1.3 (1.2-1.5)
	No	1327	8.6 (8.2-9.1)	259	1.7 (1.5-1.9)	931	6.4 (6.0-6.8)	99	0.7 (0.6-0.9)
Preterm (32-<37 w)		(n = 96 484)		(n = 96 484)		(n = 92 920)		(n = 88 837)	
	Yes	1127	1.2 (1.1-1.2)	44	0.05 (0.03-0.06)	457	0.5 (0.5-0.5)	599	0.7 (0.6-0.7)
	No	2216	2.3 (2.2-2.4)	1010	1.1 (1.1-1.1)	753	0.8 (0.8-0.9)	399	0.5 (0.4-0.5)
Term (≥37 w)		(n = 982 527)		(n = 982 527)		(n = 951 892)		(n = 914 155)	
	Yes	5743	0.58 (0.57-0.60)	322	0.03 (0.03-0.04)	2316	0.2 (0.2-0.3)	2945	0.3 (0.3-0.3)
	No	7479	0.8 (0.7-0.8)	3407	0.4 (0.4-0.4)	2289	0.2 (0.2-0.3)	1629	0.2 (0.2-0.2)

STROBE Statement—Checklist of items that should be included in reports of cohort studies.

demonstrated a decline in infant surgery rates the years from 2012 to 2017 compared with 1998 to 2002.[12] Little difference was found in the surgical care delivery for children with complex chronic conditions with Medicaid vs non-Medicaid insurance but the study population was limited to children's hospitals.[13] Knowledge of epidemiologic data of all surgical procedures, anesthetics, and imaging studies children undergo is also important for pediatric facilities and workforce management.[14]

The frequency of procedures and anesthesia in the first year of life underlines the importance of initiating surgical and anesthesia outcome studies. About 1.5% of children <3 years of age were admitted after surgery to a hospital based on the 2003, 2006, and 2009 Kid's Inpatient Database data.[4] Because only inpatient procedures were included, this number is an underestimation of procedural exposure (likely by >50% based on internal Dartmouth data), and even greater underestimation of anesthesia exposure as imaging studies (MRIs) were not included. The previously estimated exposure to at least one general anesthetic for children in a Minnesota county cohort <3 years of age was 15%.[15] In this cohort of about 20 000 children, prematurity, male sex, low birth weight, cesarean delivery, and a non-Hispanic and white mother were associated with receiving ≥1 procedure. "Estimated gestational age <32 weeks" and low birth weight were independently associated with repeated anesthesia. The Minnesota cohort differs from ours in that it is relatively small (20 000), predominantly white mothers (87%) with >72% having attained at least 12 years of education, and did not include anesthesia exposure that was not for surgical procedures (such as interventional radiology or imaging studies). Our study shows an average infant anesthesia exposure rate of 6.7%, ranging from 5% to 62% for the 4 gestational age cohorts. Extrapolating these data to the 4 million births per year in the US yields about 380 000 surgical procedures for infants per year (46 500 extremely premature, 21 500 very premature, 57 000 moderate/late premature, and 255 500 term infants). Need of anesthesia care is an estimated 300 000 for children <1 year of age per year (21 300 extremely premature, 13 000 very premature, 42 500 moderate/late premature, and 220 000 term).

Circumcisions, which were excluded in our analyses, are the most frequent procedure done on male neonates and infants (4-10 times more frequently performed than any other procedure). Circumcisions are usually performed before discharge from the initial birth admission and under local anesthesia. Interestingly, the incidence of circumcision in our population was 41.9% of boys, during the first year of life, which is lower than previously reported (55% in a private payer database, 55.9% to 80% in published literature).[16,17] One explanation for our lower circumcision rate is that our study population includes 61.3% Hispanic children, in whom the prevalence of circumcision is thought to be lower (40%-45%).[17]

Our study has some limitations. The study sample was restricted to Medicaid-insured infants limiting inference to infants with other insurance coverage. Surgeons may select patients based on insurance status, as a survey in California revealed, possibly underestimating the overall surgical events in Texas.[18,19] Our sample was from a single state, and rates vary across states.[20] In generalizing our findings to other states, the racial and ethnic composition of Texas and possible associated differences in use rates must be considered.[21] Because our data are based on CPT codes, infants may have received anesthetic agents for procedures, such as in the neonatal intensive care unit for line placements by nonanesthesiologists not using anesthesia CPT codes. Therefore, we may underestimate total exposure to anesthetic medications.

Although our study provides an in-depth insight into use of perioperative resources by infants, many questions remain to be answered. How many children have multiple anesthetics or procedures within the first 3 years of life exposing them to a potentially greater risk of neurodevelopmental changes?[22-24] How have surgical procedures, anesthesia, and imaging events changed over time to allow projections for the future? Is there racial or ethnic disparity for elective surgery and imaging studies? Is there a geographic variation in use of services? Does insurance status affect rates of exposure? Where are these services delivered? Investigating perioperative care in children is in its beginning stages, and future investigations will provide essential information for clinicians, families, and the public. ■

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Table IV. Three most common procedure types for requiring anesthesia and 3 most common procedure categories for infants (excludes imaging studies), divided by age brackets

	0-365 Days (n = 1 102 958)			0-30 Days (n = 1 102 958)			31-180 Days (n = 1 066 519)			181-365 Days (n = 1 023 356)		
Procedure types	**Description**	**Event days**	**Rate per 100 (95% CI)**	**Description**	**Event days**	**Rate per 100 (95% CI)**	**Description**	**Event days**	**Rate per 100 (95% CI)**	**Description**	**Event days**	**Rate per 100 (95% CI)**
Extreme preterm (≤28 w)	(n = 8611)			(n = 8611)			(n = 7205)			(n = 6597)		
Anesthetics	Pediatric surgery	2530	29.4 (28.2-30.5)	Cardiology	524	6.1 (5.6-6.6)	Pediatric surgery	1511	21.0 (19.9-22.0)	Pediatric surgery	432	6.6 (5.9-7.2)
	Cardiology	821	9.5 (8.9-10.2)	Pediatric surgery	399	4.6 (4.2-5.1)	Neurosurgery	324	4.5 (4.0-5.0)	ENT	257	3.9 (3.4-4.4)
	Neurosurgery	544	6.3 (5.8-6.9)	Neurosurgery	68	0.8 (0.6-1.0)	Cardiology	230	3.2 (2.8-3.6)	Radiology	240	3.6 (3.2-4.1)
Procedures	Neurosurgery	2791	32.4 (31.2-33.6)	Emergent intubations	1631	18.9 (18.0-19.9)	Brain	2147	29.8 (28.5-31.1)	Gastrostomy tubes - fundoplications	369	5.6 (5.0-6.2)
	Intubations	1820	21.1 (20.2-22.1)	PDA	642	7.5 (6.9-8.0)	Inguinal hernia repair	510	7.1 (6.5-7.7)	Scopes	291	4.4 (3.9-4.9)
	Gastrostomy tubes - fundoplications	914	10.6 (9.9-11.3)	NEC - exploratory laparotomy	268	3.1 (2.7-3.5)	Gastrostomy tubes - fundoplications	496	6.9 (6.3-7.5)	NE1: Brain	175	2.7 (2.3-3.1)
Very preterm (28-≤32 w)	(n = 15 336)			(n = 15 336)			(n = 14 502)			(n = 13 767)		
Anesthetics	Pediatric surgery	1458	9.5 (9.0-10.0)	Pediatric surgery	283	1.8 (1.6-2.1)	Pediatric surgery	874	6.0 (5.6-6.4)	Radiology	282	2.1 (1.8-2.3)
	Radiology	511	3.33 (3.0-3.6)	Cardiology	67	0.4 (0.3-0.5)	Radiology	194	1.3 (1.2-1.5)	ENT	261	1.9 (1.7-2.1)
	ENT	417	2.7 (2.5-3.0)	Neurosurgery	48	0.3 (0.2-0.4)	ENT	123	0.9 (0.7-1.00)	Pediatric surgery	237	1.7 (1.5-1.9)
Procedures	Intubations	1183	7.7 (7.3-8.1)	Emergent intubations	1032	6.7 (6.3-7.1)	Inguinal hernia repair	342	2.4 (2.1-2.6)	ENT endoscopies	147	1.1 (0.9-1.2)
	Access	453	3.0 (2.7-3.2)	Brain	133	0.9 (0.7-1.0)	Gastrostomy tubes - fundoplications	265	1.8 (1.6-2.1)	Gastrostomy tubes - fundoplications	139	1.0 (0.8-1.2)
	Inguinal hernia repair	450	2.9 (2.7-3.2)	Access	117	0.8 (0.6-0.9)	ENT endoscopies	255	1.8 (1.5-2.0)	Ear tubes	138	1.00 (0.8-1.2)
Preterm (32-<37 w)	(n = 96 484)			(n = 96 484)			(n = 92 920)			(n = 88 837)		
Anesthetics	Pediatric surgery	3685	3.8 (3.7-3.9)	Pediatric surgery	1147	1.2 (1.1-1.3)	Pediatric surgery	1701	1.8 (1.7-1.9)	ENT	1280	1.4 (1.4-1.5)
	Radiology	1892	2.0 (1.9-2.1)	Cardiology	283	0.3 (0.3-0.3)	Radiology	745	0.8 (0.7-0.9)	Radiology	965	1.1 (1.0-1.2)
	ENT	1811	1.9 (1.0-2.0)	Neurosurgery	176	0.2 (0.2-0.2)	Urology	428	0.5 (0.4-0.5)	Urology	832	0.9 (0.9-1.0)
Procedures	Access	1662	1.7 (1.6-1.8)	Emergent intubations	1087	1.1 (1.1-1.2)	ENT Endoscopies	683	0.7 (0.7-0.8)	Ear tubes	1001	1.1 (1.0-1.2)
	Emergent intubations	1440	1.5 (1.4-1.6)	GS3: Abdominal wall defects	788	0.8 (0.8-0.9)	Access	657	0.7 (0.6-0.8)	ENT endoscopies	343	0.4 (0.4-0.4)
	Scopes	1264	1.3 (1.2-1.4)	GS1: Access	595	0.6 (0.6-0.7)	Gastrostomy tubes - fundoplications	639	0.7 (0.6-0.7)	Access	332	0.4 (0.3-0.4)
Term (≥37 w)	(n = 982 527)			(n = 982 527)			(n = 951 892)			(n = 914 155)		
Anesthetics	ENT	13 579	1.4 (1.4-1.4)	Pediatric surgery	3076	0.3 (0.3-0.3)	Pediatric surgery	5196	0.6 (0.5-0.6)	ENT	11 012	1.2 (1.2-1.2)
	Pediatric surgery	11 549	1.2 (1.2-1.2)	Cardiology	1496	0.2 (0.1-0.2)	Radiology	3978	0.4 (0.4-0.4)	Radiology	4945	0.5 (0.5-0.6)
	Radiology	10 006	1.0 (1.0-1.0)	Radiology	814	0.1 (0.1-0.1)	Urology	3301	0.4 (0.3-0.4)	Urology	4744	0.5 (0.5-0.5)
Procedures	Ear tubes	10 074	1.0 (1.0-1.1)	Emergent intubations	3025	0.3 (0.3-0.3)	ENT endoscopies	3311	0.4 (0.3-0.4)	Ear tubes	9392	1.0 (1.0-1.1)
	Scopes	6514	0.7 (0.7-0.7)	Access	1457	0.2 (0.1-0.2)	Club Foot	2993	0.3 (0.3-0.3)	ENT endoscopies	1755	0.2 (0.2-0.20\)
	Access	4811	0.5 (0.5-0.5)	ENT small procedure	1360	0.1 (0.1-0.2)	GS1: Access	1882	0.2 (0.2-0.2)	Penile corrections	1278	0.1 (0.1-0.2)