Discharge Age and Weight for Very Preterm Infants: 2005–2018

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abstract

BACKGROUND: A complex set of medical, social, and financial factors underlie decisions to discharge very preterm infants. As care practices change, whether postmenstrual age and weight at discharge have changed is unknown.

METHODS: Between 2005 and 2018, 824 US Vermont Oxford Network member hospitals reported 314 811 infants 24 to 29 weeks' gestational age at birth without major congenital abnormalities who survived to discharge from the hospital. Using quantile regression, adjusting for infant characteristics and complexity of hospital course, we estimated differences in median age, weight, and discharge weight *z* score at discharge stratified by gestational age at birth and by NICU type.

RESULTS: From 2005 to 2018, postmenstrual age at discharge increased an estimated 8 (compatibility interval [CI]: 8 to 9) days for all infants. For infants initially discharged from the hospital, discharge weight increased an estimated 316 (CI: 308 to 324) grams, and median discharge weight *z* score increased an estimated 0.19 (CI: 0.18 to 0.20) standard units. Increases occurred within all birth gestational ages and across all NICU types. The proportion of infants discharged home from the hospital on human milk increased, and the proportions of infants discharged home from the hospital on oxygen or a cardiorespiratory monitor decreased.

CONCLUSIONS: Gestational age and weight at discharge increased steadily from 2005 to 2018 for survivors 24 to 29 weeks' gestation with undetermined causes, benefits, and costs.

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WHAT'S KNOWN ON THIS SUBJECT: A preterm infant generally reaches physiologic stability and functional maturation at ~36 weeks' postmenstrual age. As neonatal intensive care practices have evolved, whether postmenstrual age and weight at discharge have changed is unknown.

WHAT THIS STUDY ADDS: Postmenstrual age increased 8 days for all infants, and weight increased 316 g or 0.19 standard units on *z* score for infants discharged from the hospital across all birth gestational ages and NICU types. Changes in clinical practices may explain these increases.

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A complex set of medical, social, and financial factors underlie the decision to discharge a very preterm infant from a NICU.[1,2] Of primary concern is an infant's physiologic stability and functional maturation, which generally occurs at ~36 weeks' postmenstrual age.[3,4] Equally important are the needs to establish discharge readiness;[5] find an infant's medical home;[6] assess housing, psychosocial support, and other social needs;[7] and take appropriate steps to follow through to address the social determinants of health.[8]

Given that, the optimal discharge age and weight for stable preterm infants are largely unknown. Historically, discharge occurred when infants achieved a certain weight.[2] However, in 3 randomized trials in which infants who were discharged when physiologically ready were compared with those discharged at a set weight[9,10] or by physician discretion,[11] no adverse consequences of earlier discharge were found. The savings associated with earlier discharge were substantial, from $18 560 per infant in 1986[10] or $43 686 in 2020 dollars,[12] to $5016 per infant in 2002[13] or $7307 in 2020 dollars,[12] and the effect of prolonged hospital stays on families is equally as important as financial interests. However, these trials were conducted in an earlier era of neonatal intensive care, when treatment practices and survival rates for extremely preterm infants were much different from how they are today.

We have observed reductions in neonatal mortality and morbidities,[14,15] increases in the use of evidence-based care practices,[16] and increases in growth velocity during the birth hospitalization[17] since 2000. We sought to describe changes in discharge weight and age for very preterm infants in the United States from 2005 to 2018.

METHODS

Vermont Oxford Network (VON) is a voluntary worldwide community of practice dedicated to improving the quality, safety and value of newborn care through a coordinated program of data-driven quality improvement, education, and research. The University of Vermont institutional review board determined that use of data from the VON Research Repository for this analysis was not human subjects research.

US hospitals with NICUs contributed data on infants 401 to 1500 g or 22 0/7 to 29 6/7 weeks' gestational age at birth who were inborn or transferred to the reporting hospital within 28 days of life from January 1, 2005, to December 31, 2018. All data were collected by local staff using standard definitions.[18]

We included all live-born infants born at 24 0/7 to 29 6/7 weeks' gestation without major congenital anomalies who survived to discharge from the hospital. We calculated postmenstrual age at discharge as gestational age at birth in days plus total length of stay in days. Transferred infants' length of stay was tracked by the reporting hospitals until ultimate disposition. We assessed discharge weight only for infants initially discharged from the hospital because we did not have weight at ultimate disposition for transferred infants. The *z* scores for weight at birth and discharge up to 50 weeks' postmenstrual age were calculated by using the Fenton growth chart.[19] The *z* scores for discharge after 50 weeks' postmenstrual age were calculated by using the World Health Organization Child Growth Standards with corrected age.[20]

To evaluate clinical factors that may influence discharge age, we evaluated, separately, the proportions of infants who were discharged from the hospital on oxygen, on cardiorespiratory monitors, or on any human milk. We also evaluated the proportion of infants transferred to assess whether changes in transfer could explain observed changes.

Hospital characteristics were derived from the VON annual member survey. By using responses to whether the center was required by state regulation to transfer infants to another center for assisted ventilation on the basis of the infant characteristics or duration of ventilation required or whether 1 of 8 surgeries was performed at the center (omphalocele repair, ventriculoperitoneal shunt, tracheoesophageal fistula and/or esophageal atresia repair, bowel resection and/or reanastomosis, meningomyelocele repair, PDA ligation, cardiac catheterization, or cardiac surgery requiring bypass), centers were divided into 4 groups: ventilation restrictions; no surgery; surgery except cardiac requiring bypass; and all surgery. Teaching hospitals included those in which pediatric residents, neonatology fellows, or other residents (family practice, obstetrics, anesthesia, etc) participated in direct patient care in the NICU.

We stratified infants by week of gestational age at birth and evaluated the median age and weight at discharge from 2005 to 2018 (Figs 1 and 2). We used quantile regression[21,22] to estimate the annual change in median age, weight, and weight *z* score at discharge, adjusting for differences in infant and delivery characteristics, including year of birth, gestational age at birth, 1-minute Apgar score, small size for gestational age, cesarean delivery, sex, multiple gestation, and birth location (inborn or outborn). We estimated changes in medians over the 14 years with 95% compatibility intervals (CIs).[23] We stratified models by week of gestational age and by NICU

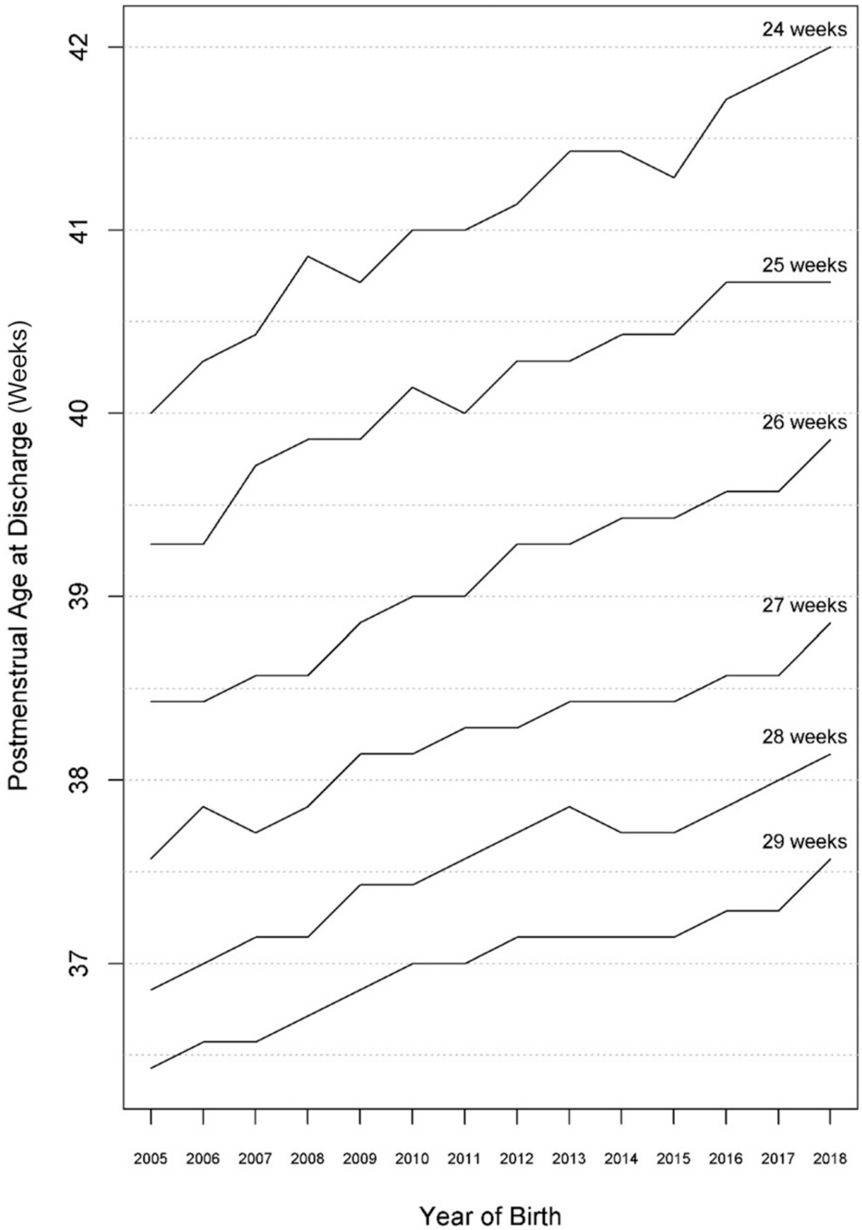

FIGURE 1
Median gestational age at discharge in weeks for infants born at 24 to 29 weeks' gestational age who survived to discharge from the hospital, 2005–2018.

type to estimate differences over time within these categories.

RESULTS

Over the 14 years, 824 hospitals contributed data, of which 47% were teaching hospitals, 72% were nonprofit, 51% had surgical capabilities, and 8% were freestanding children's hospitals. Overall, 314 811 infants met eligibility criteria. During the study period, hospitals with restrictions on ventilation contributed 1.5% of infants, hospitals that did not do surgery contributed 16%, hospitals that did surgery except cardiac surgery requiring bypass contributed 52%, and hospitals that did all surgeries contributed 31%. Characteristics of 2005 and 2018 cohorts that are included in the quantile regression models are in Table 1.

The median postmenstrual age at discharge from the hospital for the overall population was 38.3 weeks (interquartile range [IQR]: 36.6–40.7). Figure 1 reveals the median postmenstrual age at discharge by gestational age at birth and birth year from 2005 to 2018. Over the 14 years, median unadjusted postmenstrual age at discharge increased 9 days, and median adjusted age increased an estimated 8 days (95% CI: 8 to 9). The risk-adjusted estimates of the differences from quantile regression models by gestational age and NICU type are in Table 2.

The median weight at discharge from the hospital for the 273 109 infants initially discharged from the hospital was 2600 g (IQR: 2260–3078). Figure 2 reveals the median weight at discharge by gestational age at birth and birth year from 2005 to 2018. Over the 14 years, median unadjusted weight at discharge increased 360 g and median adjusted weight at discharge increased an estimated 316 g (95% CI: 308 to 324). Risk-adjusted estimates by gestational age and NICU type are in Table 2.

Figure 3 reveals the median z score for weight at discharge by gestational age at birth and birth year from 2005 to 2018. Over the 14 years, median unadjusted z score for weight increased 0.22 standard units and median adjusted z score for weight at discharge increased an estimated 0.19 standard units (95% CI: 0.18 to 0.20). Risk-adjusted estimates by gestational age and NICU type are in Table 2.

From 2005 to 2018, the proportion of infants who were discharged from the hospital on any human milk increased

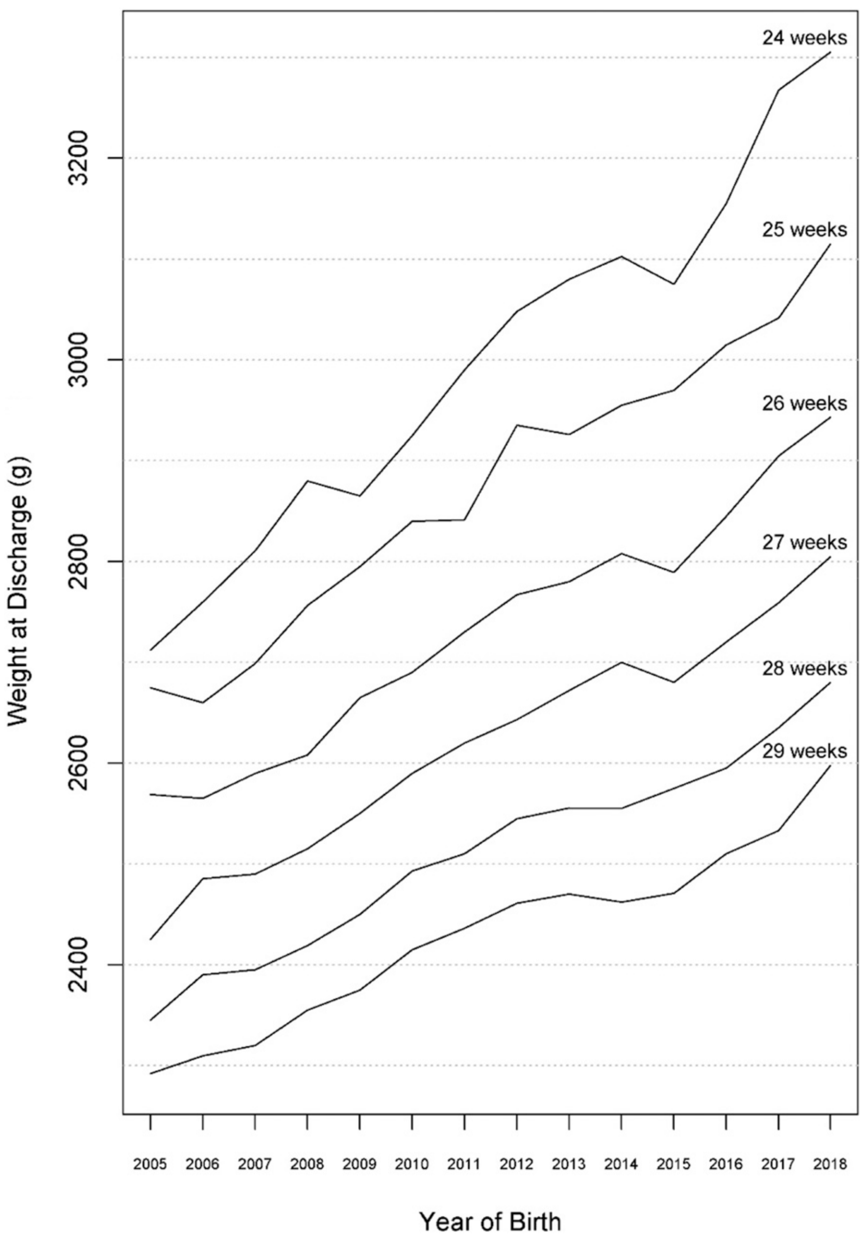

FIGURE 2
Median weight at discharge in grams for infants born at 24 to 29 weeks' gestational age who were initially discharged from the hospital, 2005–2018.

from 40% to 48%. Among infants initially discharged from the hospital, the proportion discharged on a cardiorespiratory monitor decreased from 49% to 26%, whereas those discharged on oxygen decreased from 27% to 22%. The proportion of infants who were never transferred increased from 71% to 76%.

DISCUSSION

In this large cohort of infants born 24 to 29 weeks' gestational age and admitted to 824 NICUs in the United States who survived to initial discharge, adjusted postmenstrual discharge age increased by 8 days (95% CI: 8 to 9) from 2005 to 2018, adjusted discharge weight increased by 316 g (95% CI: 308 to 324), and adjusted median z score for weight at discharge increased by 0.19 standard units (95% CI: 0.18 to 0.20) across all gestational ages and NICU types. If 1 day in the NICU costs $3000,[24] or $3572 in 2020 dollars,[12] then an extra 8 days could cost an additional $28 576 if every day of a NICU stay costs the same amount. Moreover, this increase means that families and infants are separated for >1 week longer today than they were 14 years ago. Whether the increased separation leads to better preparation for discharge is unknown because optimal discharge age and weight are largely unknown.

Before adjustment, median postmenstrual age at discharge increased 9 days and median discharge weight increased 360 g. More infants survived in 2018 than in 2005, and it is possible that infants who would not have survived in 2005 were surviving in 2018 and required more time to reach physiologic maturity before discharge. However, after adjusting for infant characteristics at birth, the gestational age and weight at discharge still increased dramatically over the time period.

The proportion of infants discharged from the hospital on any human milk, which includes exclusive human milk and human milk plus fortifier, increased from 2005 to 2018. Nutritional management quality improvement efforts[25–29] and the Baby-Friendly Hospital Initiative[30] may have contributed to the increased discharge weight and decreased growth failure, although we do not know whether similar improvements in nutrition and human milk could be achieved in shorter stays or whether the improvements were a result of the longer stays. The American Academy of Pediatrics recommends human milk[31] because it protects against life-threatening

TABLE 1 Comparison of Infant Characteristics, 2005 and 2018

	2005 Infants, *n* = 19 469	2018 Infants, *n* = 21 998
At birth		
Gestational age, mean ± SD[a]	27.1 ± 1.6	27.1 ± 1.6
1-min Apgar score, median (IQR)[a]	6 (4–7)	5 (3–7)
Small for gestational age, *n* (%)[a]	1182 (6.1)	1674 (7.6)
Cesarean delivery, *n* (%)[a]	13 426 (69.0)	15 788 (71.8)
Male sex, *n* (%)[a]	10 155 (52.2)	11 350 (51.6)
Multiple gestation, *n* (%)[a]	5121 (26.3)	5015 (22.8)
Inborn at reporting hospital, *n* (%)[a]	16 032 (82.3)	19 064 (86.7)
Neonatal course, *n* (%)		
Delivery room intervention[a,b]	16 091 (82.7)	17 203 (78.2)
Ventilation after initial resuscitation[a]	16 207 (83.3)	14 926 (67.9)
Any surgery[a]	4561 (23.4)	3813 (17.3)
Morbidities, *n* (%)		
Respiratory distress syndrome[a]	17 035 (87.5)	18 452 (83.9)
Early bacterial sepsis	415 (2.1)	247 (1.1)
Any late infection	5100 (26.3)	1968 (9.0)
Severe intraventricular hemorrhage	1545 (8.1)	1431 (6.7)
Necrotizing enterocolitis or gastrointestinal perforation	1663 (8.6)	1337 (6.1)
Pneumothorax	792 (4.1)	890 (4.0)
Chronic lung disease	7171 (38.3)	7299 (34.0)

a Included in risk adjustment model.

b Includes face mask ventilation, endotracheal tube ventilation, cardiac compression, epinephrine, or surfactant in the delivery room.

complications of preterm birth.[32] We previously found that infants discharged on human milk alone or in combination with formula showed improvements in weight *z* score change and weight gain velocity from 2012 to 2016 similar to formula-fed infants.[33] Still, disparities by race and ethnicity persist, with non-Hispanic Black and Native American infants less likely than non-Hispanic white infants to be discharged on any human milk.[33]

TABLE 2 Adjusted Differences in Median Discharge Age in Days and Weight in Grams, With 95% CIs, From 2005 to 2018

	Change in Discharge Age (CI), d	Change in Discharge Wt (CI), g	Change in Discharge Wt (CI), *z* Score
Overall	8 (8 to 9)	316 (308 to 324)	0.19 (0.18 to 0.20)
Gestational age at birth, wk			
24	13 (12 to 14)	533 (492 to 574)	0.49 (0.44 to 0.54)
25	10 (9 to 11)	434 (402 to 465)	0.42 (0.38 to 0.46)
26	9 (8 to 10)	376 (351 to 400)	0.29 (0.25 to 0.32)
27	8 (8 to 9)	315 (296 to 334)	0.20 (0.17 to 0.22)
28	8 (7 to 8)	288 (273 to 304)	0.13 (0.11 to 0.15)
29	7 (6 to 7)	248 (235 to 260)	0.08 (0.07 to 0.10)
NICU type			
Restrictions on ventilation	8 (7 to 10)	279 (224 to 335)	0.05 (−0.03 to 0.12)
No surgery	8 (8 to 9)	278 (260 to 296)	0.09 (0.07 to 0.11)
No restrictions on ventilation and no surgery except cardiac surgery requiring bypass	8 (8 to 8)	321 (310 to 331)	0.21 (0.20 to 0.22)
No restrictions on ventilation and all surgery, including cardiac surgery requiring bypass	10 (9 to 10)	365 (349 to 381)	0.19 (0.17 to 0.21)

Fewer infants were discharged from the hospital with respiratory monitoring and oxygen support. Apnea of prematurity and bradycardia events, which typically resolve between 37 and 43 weeks' postmenstrual age,[3,34,35] require observation around the time of discharge. However, in a study of >1400 premature infants, Lorch et al[4] found that many did not have future apnea or bradycardia events when they were otherwise ready for discharge. They suggested that gestational age at birth, chronological age at observation, and days off methylxanthines should be considered when deciding whether an infant will be event-free at discharge.[4] Instead, they observed that most NICUs have protocols determining the length of observation needed for apnea and bradycardia at the time of discharge. One study found this observation time ranged from 1 to 21 days,[36] although the majority of neonatologists require a 5 to 7-day observation period without apnea or bradycardia events before discharge.[37] Whether infants were discharged later to establish cardiorespiratory maturity or because of policies governing the number of days infants must be observed to be apnea free before discharge is unknown. The work of Walsh et al[38,39] on timed room-air challenges for bronchopulmonary dysplasia were published just before our study period began and may play a role in increased length of stay, better growth, and decreased rates of discharge on oxygen support.[40]

This study's limitations include lack of information on discharge policies at the NICU level, which would give us additional insights into why we observed these increases. Infants may be staying longer because of misaligned financial incentives;

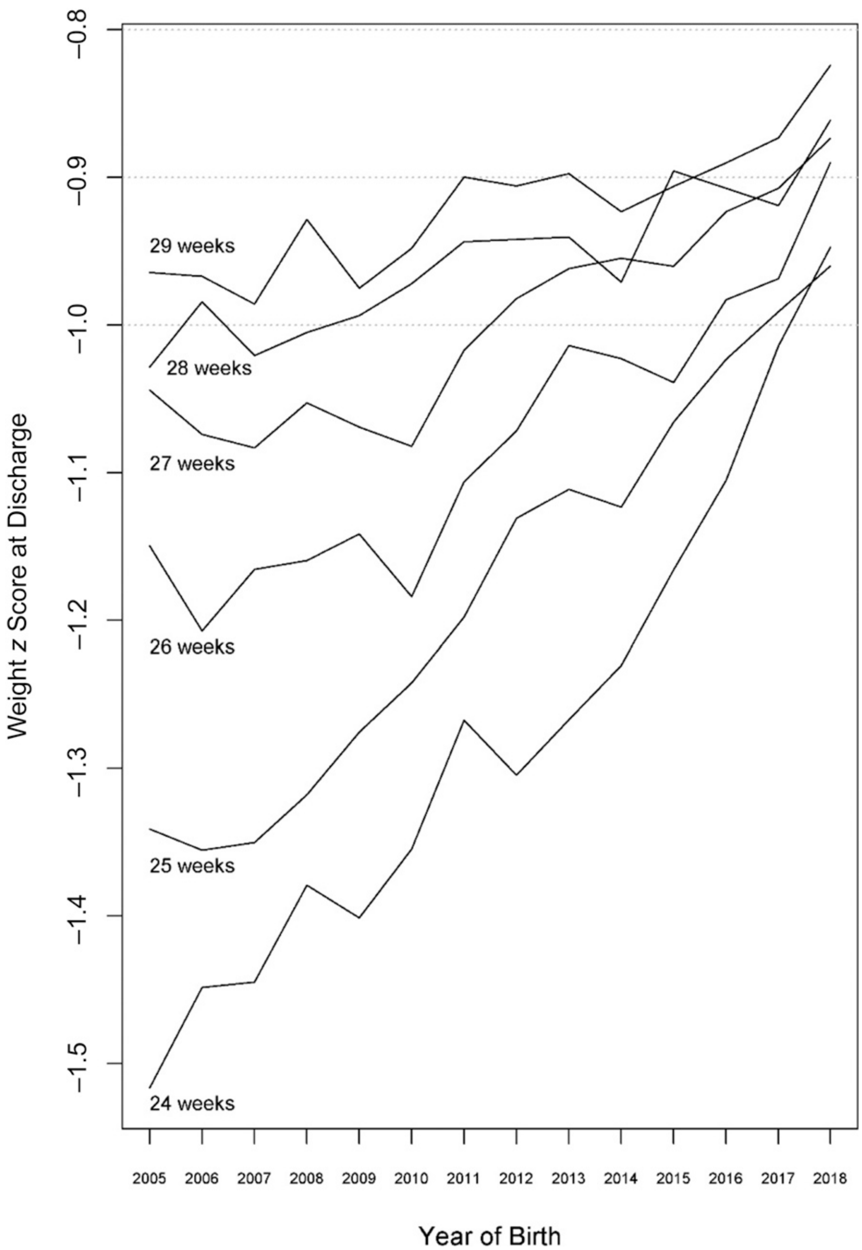

FIGURE 3
Median *z* score for weight at discharge for infants born at 24 to 29 weeks' gestational age who were initially discharged from the hospital, 2005–2018.

when payment is based on fee for service, physician reimbursement and other incentives may lead to longer stays. We do not know to what extent financial incentives may be playing a role. We also do not know staffing issues at the NICU level that might influence timing of discharge. For example, Profit et al[41] found that NICU census and the patient-nurse ratio influenced discharge of moderately preterm infants, whereas Silber et al[13] observed a decreased rate of discharge on weekends and increased rates on Mondays and Fridays. We do not know readmission rates for infants, and we do not have enough information to determine causal mechanisms for increased discharge age or weight. There could be unmeasured differences in survivors that could contribute to the findings.

CONCLUSIONS

Gestational age and weight at discharge increased steadily from 2005 to 2018 for infants 24 to 29 weeks' gestation. The benefits, costs, and harms of increased age and weight at discharge are undetermined. Nonetheless, families and infants are separated for more than a week longer today than they were 14 years ago. The effects of prolonged separation cannot be underestimated.

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ABBREVIATIONS

CI: compatibility interval
IQR: interquartile range

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