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Inter-Neonatal Intensive Care Unit Variation in Discharge Timing: Influence of Apnea and Feeding Management

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ABSTRACT. ***Background.*** **Premature infants need to attain both medical stability and maturational milestones (specifically, independent thermoregulation, resolution of apnea of prematurity, and the ability to feed by mouth) before safe discharge to home. Current practice also requires premature infants to be observed in hospital before discharge for several days (margin of safety) after physiologic maturity is recognized.**

Objective. **To compare postmenstrual age (PMA) at discharge in a homogeneous population of premature infants cared for in different neonatal intensive care units (NICUs) and to assess the impact on hospital stay of the recognition and recording of physiologic maturity and the required margin of safety.**

Methods. **We studied premature infants delivered at 30 to 34 6/7 weeks gestational age (GA), free of significant medical or surgical complications. Medical records of 30 eligible infants consecutively discharged from the hospital before July 1997 from each of 15 NICUs in Massachusetts (9 level 2 and 6 level 3) were reviewed.**

Results. **A total of 435 infants were included in the study sample. Mean (± standard deviation) GA and birth weight of the study population were 33.2 ± 1.2 weeks and 2024 ± 389 g, respectively. Infants were discharged at a similar PMA regardless of GA at birth. Considerable variation in the PMA at discharge between hospital sites was observed (range, 35.2 ± 0.5 weeks to 36.5 ± 1.2 weeks). Despite the homogeneous study population, hospitals in which infants had the latest PMA at discharge also recorded mature cardiorespiratory and feeding behavior at an older age. Longer duration of pulse oximetry use was associated with later resolution of apnea. Differences in the duration of the margin of safety between sites did not contribute to variation in hospital stay.**

Conclusion. **NICUs vary widely in length of hospital stay for healthy premature infants. We speculate that this variation results in part from differences in monitoring for and documentation of apnea of prematurity and feeding behavior.** ***Pediatrics*** **2001;108:928–933;** ***newborns, apnea of prematurity, practice variation, hospital discharge, neonatal intensive care units.***

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ABBREVIATIONS. NICU, neonatal intensive care unit; GA, gestational age; PMA, postmenstrual age; PG, per gavage.

For premature infants, length of stay in the neonatal intensive care unit (NICU) is influenced by a number of factors but is most strongly affected by gestational age (GA) and weight at birth.[1] Infants delivered at the earliest GAs have the longest hospital stays, in part because of the higher incidence of medical complications in extremely low birth weight infants. However, in contrast to adult and other pediatric patients, premature infants are unique in their need to attain not only medical stability but also physiologic maturity, including adequate temperature control, cessation of apnea and bradycardia, and the ability to feed by mouth, before safe discharge to home. These markers of maturity typically are observed after 35 weeks' postmenstrual age (PMA)[2] and may be further delayed in infants delivered at the youngest GAs.[3,4] After they attain these maturational milestones, most premature infants are observed before discharge for several days. This additional margin of safety before discharge contributes to total length of hospital stay.

NICUs differ in the medical care of sick premature infants, including ventilatory management,[5–8] blood transfusion practice,[9] and narcotic use.[10] Despite documentation of variation in medical care during hospitalization, little is known about factors that might influence inter-NICU variation in total length of hospital stay. It is likely that NICU care providers differ in their treatment of premature infants as they approach physiologic maturity and may demand a shorter or longer margin of safety before discharge. In a 1996 survey, the majority of neonatologists required observation for 5 to 7 days between the last documented apneic spell and discharge to home, but responses varied from 1 to 10 days.[4] The objective of this study was to compare discharge timing in a homogeneous population of healthy premature infants cared for in different Massachusetts NICUs. We hypothesized that inter-NICU variation in the recognition and documentation of physiologic maturity and the required margin of safety before discharge would affect length of stay in individual NICUs.

METHODS

Population

The study group consisted of premature infants delivered at 30 to 34 6/7 weeks' GA. A homogeneous, healthy population was chosen to minimize any potential effects on discharge timing by illness severity and other medical complications. Details of the exclusion criteria for the study are shown in Table 1; both inborn and outborn infants were included. Medical records of 30 eligible premature infants consecutively discharged to home before July 1997 from each of 9 level 2 and 6 level 3 NICUs in Massachusetts were reviewed. The use of equal sample sizes per site and an identification code (numbers 1–15) helped preserve the anonymity of the NICUs. Identity of the NICUs was known only to a single investigator (D.K.R.).

Definitions and Data Collection

Chart abstractors at each site were trained by a single individual and used a common abstraction tool. Chart abstraction included infant and maternal demographic data, GA at birth (based on best obstetrical estimate), growth parameters, and a variety of clinical parameters including dates of last documented apnea or bradycardia episode, last nasogastric or orogastric (PG) feeding, last day in an incubator, and discharge to home. These dates were then used to calculate PMA at achievement of these maturational milestones and the interval between each milestone and discharge to home. Recordings of apnea or bradycardia were based on nursing observations of monitor alarms and documented assessment of the infant's clinical condition at the time of the alarm. Documentation of the last apnea or bradycardia episode included both self-resolved events and those necessitating intervention and did not differentiate between spells that occurred on or off methylxanthine therapy.

We defined physiologic maturity as maintaining temperature in an open crib, being free of apnea or bradycardia events, and taking full-volume feeds orally (breast or bottle). The margin of safety was defined as the number of elapsed days until discharge after infants were first documented to have reached physiologic maturity. After chart abstraction was completed, collected data were reviewed to ensure that all infants included in the analysis met inclusion criteria. The study was approved by the institutional review boards at all 15 sites.

Analyses

We performed 2 parallel sets of analyses: by GA (in completed weeks) and by hospital site. The GA analyses focused on the distribution of PMA at attainment of selected maturational milestones (thermoregulation out of incubator, cessation of apnea, successful full oral feeding) and discharge to home and the synchronization of these milestones to PMA (regardless of GA at birth). The individual hospital analyses focused on the extent to which hospitals differ in recognizing these maturational milestones, the duration of the clinician-driven margin of safety, and its impact on discharge timing. Univariate analysis was used to compare the GA groups and hospital sites. Multivariate regression, using the hospital with the earliest discharge as reference, was used to predict the PMA at discharge as a function of time to thermoregulation out of the incubator, resolution of apnea of prematurity, time to full oral feedings, and the interval between each and discharge to home. Differences were considered significant if $P < .05$.

TABLE 1. Study Population Inclusion and Exclusion Criteria

Infants 30–34 6/7 wks gestational age
Exclusion criteria
Site hospital length of stay <48 h
Small for gestational age
Mechanically ventilated for >3 d
Supplemental oxygen for >7 d
Intraventricular hemorrhage of any severity
Culture-positive infection (blood or urine)
Known or presumed meningitis
Necrotizing enterocolitis (medical or surgical)
Any surgery, including herniorrhaphy

RESULTS

Population

A total of 450 infants were included in the chart abstraction; 15 infants were excluded from the final analysis after they were found not to meet inclusion criteria. The final study sample consisted of 435 infants, ranging from 27 to 30 per hospital site. By design, this was a homogeneous population of healthy, moderately premature infants (Table 1). Of the final study sample, 250 infants (58%) were male. The mean (± standard deviation) GA and birth weight of the study population were 33.2 ± 1.2 weeks and 2024 ± 389 g, respectively.

Analyses by GA Groups

Clinical characteristics of the study population grouped by completed gestational weeks at birth are presented in Table 2. Regardless of GA at birth, infants were discharged from the hospital at a nearly identical PMA of 35 to 36 weeks (Table 2). PMA at discharge was normally distributed, with mean of 35.8 ± 0.97 weeks.

The proportion of infants who demonstrated immature thermoregulation, cardiorespiratory control, or feeding behavior was correlated with GA at birth (Table 2). Nearly all infants delivered at 30 weeks needed PG feeds and suffered apneic events, with progressive decreases in the prevalence with advancing GA. Despite the differences at the beginning of their NICU stay, all infants achieved independent thermoregulation, resolution of apnea, and full oral feedings in a consistent timed sequence, with means of 34.0 ± 0.8, 34.3 ± 1.3, and 34.5 ± 1.1 weeks, respectively, regardless of GA at birth. Individual infants had a consistent pattern of maturation. The postnatal day on which infants accomplished full oral feedings was strongly correlated with the last postnatal day with a documented apnea or bradycardia event in all GAs ($P < .001$; Fig 1). When the 30- to 33-week infants were compared with the 34-week infants, small but statistically significant differences in the PMA at attainment of physiologic maturity were observed (Table 2), with the gestationally younger infants reaching physiologic maturity at a slightly lower PMA than the 34-week infants. The elapsed time between attainment of physiologic maturity and discharge to home was 1 to 2 days longer for infants delivered at the younger GAs than for those delivered at 34 weeks (Table 2). Few infants at any GA were discharged with a home monitor or methylxanthine therapy (Table 2).

Analyses by Site

Baseline mean GA at birth was similar among hospitals with 2 exceptions (Table 3). However, PMA at discharge varied widely between hospitals (Fig 2; Table 3). The PMA at discharge for all sites ranged from a low of 35.2 ± 0.5 weeks (site 1) to a high of 36.5 ± 1.2 weeks (site 15; Fig 2, Table 3). The hospital with the earliest PMA at discharge (site 1) was used as the reference site for subsequent analyses.

We examined the variation between sites in the time documented to attain physiologic maturity

TABLE 2. GA Analysis

	GA (weeks)				
	30 (n = 25)	31 (n = 40)	32 (n = 95)	33 (n = 122)	34 (n = 153)
Birth weight (g)	1445 ± 255	1752 ± 285	1800 ± 235	2060 ± 272	2298 ± 336
Discharge weight (g)	2220 ± 232	2293 ± 342	2181 ± 273	2276 ± 328	2318 ± 314
PMA at last apnea (weeks)	34.6 ± 1.9*	34.5 ± 1.1*	34.6 ± 1.1*	35.5 ± 1.3	35.4 ± 0.9
PMA at last orogastric or nasogastric feed	34.6 ± 1.2*	34.3 ± 0.9*	34.7 ± 0.9*	34.9 ± 1.1*	35.5 ± 0.8
PMA last in incubator	33.9 ± 0.9*	33.9 ± 0.9*	34.2 ± 0.7*	34.7 ± 0.7*	34.9 ± 0.5
PMA at discharge to home	35.8 ± 1.2	35.6 ± 0.9	35.6 ± 0.9	35.9 ± 1.1	35.9 ± 0.8
Margin of safety (days)	6.5 ± 3*	7.3 ± 5*	6.3 ± 5*	6.2 ± 4.3*	4.9 ± 3.5
Number with apnea (%)	23 (92)	36 (90)	56 (59)	59 (48)	46 (30)
Number needing orogastric or nasogastric feeds	25 (100)	36 (90)	82 (86)	80 (66)	64 (42)
Number needing incubator	23 (92)	34 (85)	83 (87)	102 (84)	110 (72)
Discharge with home monitor	4 (16)	4 (10)	4 (4)	3 (2.5)	5 (3)
Discharge with methylxanthines	3 (12)	2 (5)	5 (5)	3 (2.5)	1 (0.7)

* $P < .05$ compared with 34 weeks.

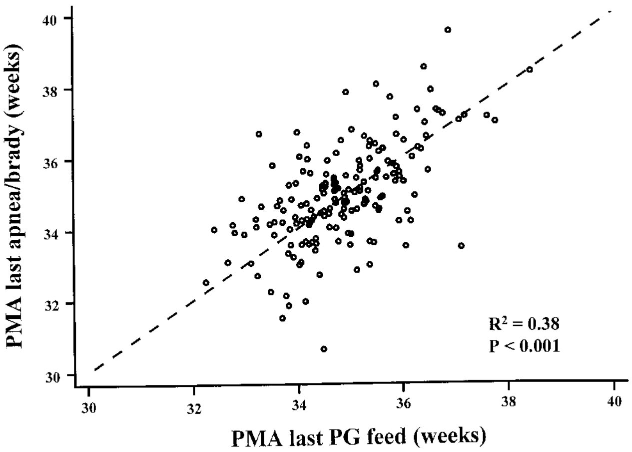

Fig 1. Scatterplot of PMA at last apnea or bradycardia episode versus PMA at last required PG feeding for all infants who had apnea or PG feeds recorded. Identity is shown with the dashed line. The PMA at last apnea or bradycardia episode was strongly correlated with the PMA at last PG feeding ($P < .001$).

TABLE 3. Hospital Site Admission GA and Discharge PMA

Site	GA at Birth (weeks)	PMA at Discharge
1	33.5 ± 0.9	35.2 ± 0.5
2	32.9 ± 1.1	35.3 ± 0.7
3	33.7 ± 0.9	35.4 ± 0.6
4	32.8 ± 1.6*	35.5 ± 0.6
5	32.9 ± 1.2	35.5 ± 0.8
6	33.2 ± 1.4	35.6 ± 0.9*
7	32.4 ± 1.2*	35.6 ± 1.0*
8	33.0 ± 1.2	35.8 ± 0.7*
9	33.7 ± 1.0	35.8 ± 1.0*
10	33.5 ± 1.2	35.9 ± 0.7*
11	33.3 ± 1.1	36.0 ± 0.9*
12	33.3 ± 0.9	36.1 ± 1.2*
13	33.3 ± 1.1	36.1 ± 1.2*
14	32.9 ± 1.4	36.5 ± 1.1*
15	33.2 ± 1.0	36.5 ± 1.2*

* $P < .05$ compared with site 1.

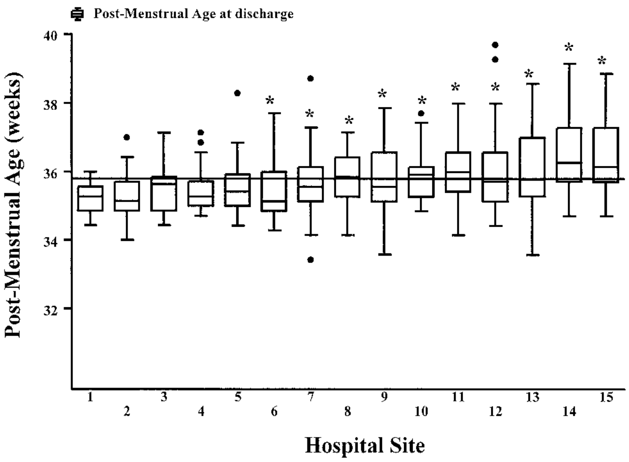

Fig 2. Box-and-whiskers plot of the PMA at discharge by hospital site; in this and subsequent figures sites are ordered 1 through 15 based on mean PMA at discharge. Boxes enclose the 25th to 75th percentiles, with the mean indicated by the horizontal bar. The 5th and 95th percentiles are indicated by the whiskers. Outliers are indicated by the solid circles. PMA at discharge ranged from 35.2 ± 0.5 weeks at site 1 to 36.5 ± 1.2 weeks at site 15. *Significant differences in discharge timing using hospital 1 as reference ($P < .05$).

when immature thermoregulation, apnea, or immature feeding behavior was recorded any time during the hospital stay. Using the hospital with earliest discharge as reference (site 1), we observed differences between sites in the PMA at last documented apnea or bradycardia event (Fig 3), day of last recorded PG feeding (Fig 4), and the day of independent thermoregulation (data not shown). These observations were confirmed by multivariate regressions corrected for the GA at birth. Six of the 8 sites with significantly later PMA at last apnea also had a later PMA at last PG feeding; 5 of these 8 sites also had a later PMA for the day of independent thermoregulation. As expected, there was a strong correlation between the PMA at resolution of apneic events and attainment of mature feeding behavior and the PMA at discharge for all sites ($P < .001$). The length of the interval between physiologic maturity and discharge home varied widely among sites (Fig 5); however, the margin of safety before discharge was not consistently longer in sites with later discharge to home. Results were similar if only the delay between the last apneic or bradycardic event and discharge was used for the analysis.

After observing site differences in the recorded duration of apnea, we investigated the possible effect of differences in monitoring practices on the documented PMA at last apnea or bradycardia episode.

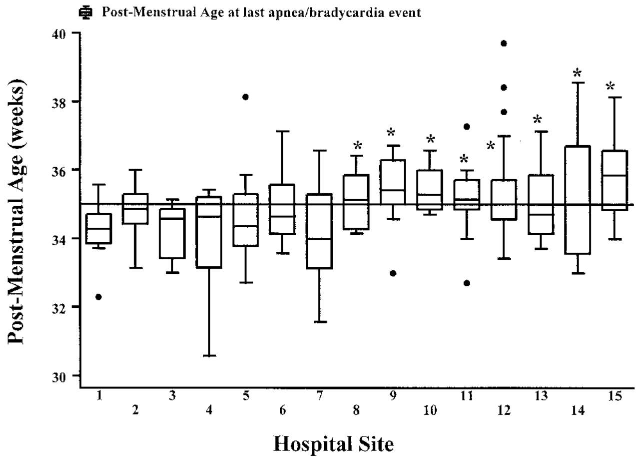

Fig 3. Box-and-whiskers plot of PMA at last documented apnea or bradycardia episode by hospital site, ordered from 1 to 15 as in Fig 1. Hospitals with later PMA at discharge also documented later resolution of apnea or bradycardia events. *Significant differences using hospital 1 as reference ($P < .05$).

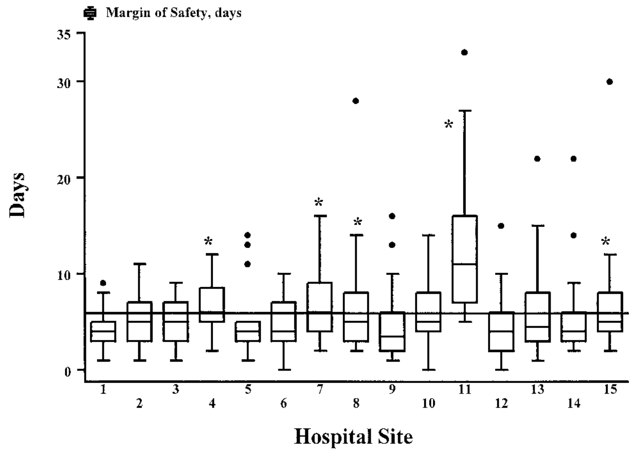

Fig 5. Box-and-whiskers plot of the margin of safety in days by hospital site. Although variability in the margin of safety was observed, it did not systematically affect discharge timing. *Significant differences using hospital 1 as reference ($P < .05$).

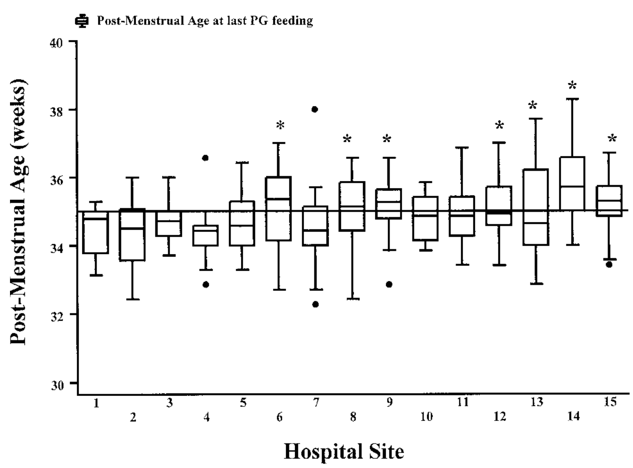

Fig 4. Box-and-whiskers plot of PMA at last required PG feeding by hospital site. Six of the 8 hospitals with later apnea resolution also had later documented development of mature feeding behavior. *Significant differences using hospital 1 as reference ($P < .05$).

All sites continued to use cardiorespiratory monitoring (electrocardiogram and impedance apnea monitor) until discharge to home. There were significant differences in the duration of pulse oximetry use between sites ($P < .001$). Five of the 8 sites with the latest documented resolution of apnea events also had significantly longer duration of pulse oximetry use.

Using multivariate regression, we analyzed other clinical parameters that may have influenced documented physiologic maturity and discharge timing and confounded inter-NICU differences. Discharge timing was not affected by the level of NICU care (level 2 or 3), GA distribution at individual sites, feeding method at discharge (breast or bottle), or sex. Infants with a birth weight at a higher percentile for GA (birth weight z score) were discharged sooner, and those outborn from the discharging NICU were discharged later. However, when the model was corrected for birth weight z score and outborn status in addition to GA at birth, significant unexplained inter-NICU variation in discharge timing persisted. We did not analyze data on socioeconomic status of the parents, insurance coverage, or postdischarge pediatric care, which also might have influenced discharge timing, to protect the anonymity of the hospital sites.

DISCUSSION

Length of hospital stay in premature infants is most strongly influenced by GA at birth and birth weight.[1–3] Despite studies that document a predictable pattern of attainment of maturational milestones in premature infants necessary for safe discharge to home,[3,4] little is known about how variation in management or discharge practices among practitioners or NICUs affects length of stay. We hypothesized that inter-NICU variation in the recognition and documentation of physiologic maturity and the required margin of safety before discharge would affect length of stay in individual NICUs.

When analyzed by GA groups, we observed the expected progression of more mature behavior with older GA at birth (Table 2). Although the occurrence of apnea and the need for PG feeds usually are well documented, we did not record reasons for incubator use because this is often difficult to assess from the medical record. It is possible that incubator use, especially in the gestationally older infants, was not related to immature temperature regulation but rather to other nursing issues (eg, phototherapy). Although the 34-week infants attained physiologic maturity at a slightly older PMA, the margin of safety was slightly longer in the younger infants. Thus, the PMA at discharge was nearly identical across the GA groups.

In contrast to the GA group analysis, length of hospital stay varied significantly between the 15 NICUs. The interval between the earliest and latest discharging NICU was approximately 1.5 weeks. Differences in the PMA at discharge across sites remained significant when corrected for GA at birth and other clinical factors that affected discharge timing, including birth weight z score and outborn status. Other clinical parameters examined, including hospital level of care, feeding method at discharge (breast or bottle), and sex did not affect the distribution of PMA at discharge.

Because our study sample was a homogeneous population of premature infants free of significant medical or surgical complications, we expected that the distribution of PMA at attainment of physiologic maturity would be similar across sites. However, NICUs varied widely in the PMA at resolution of apnea of prematurity, oral feeding (Figs 3 and 4), and independent thermoregulation. This inter-NICU variation in recorded attainment of maturational milestones was the most significant influence on length of stay. In contrast, the margin of safety, although slightly different between NICUs, did not systematically alter discharge timing (Fig 5).

It is possible that despite our restrictive inclusion criteria, subtle differences between hospitals in severity of illness may have influenced the development of physiologic maturity and hence the PMA at discharge. However, infants born at the youngest GAs included in this study, who might be expected to be sicker at birth, attained documented physiologic maturity at a slightly earlier PMA than the 34-week infants (Table 2). In addition, GA at birth had no effect on PMA at discharge. We included both inborn and outborn infants in the study population, which should have obscured any differences in initial severity of illness between hospitals. Indeed, no effect of the level of care provided at the hospitals on PMA at discharge was observed. We are aware of no data that demonstrate that other biological or demographic factors that might differ between hospitals, such as ethnicity, sex, or socioeconomic status, might alter the development of physiologic maturity in premature infants. Our results strongly suggest that variation in care practices, rather than differences in clinical characteristics, contributed to differences in the recognition of maturity, and hence discharge timing, between hospitals.

In the absence of a GA or other biological effect, the inter-NICU differences we observed in the timing of apnea resolution could be influenced by several factors, including monitoring methods used to detect apnea or bradycardia and documentation practices. We observed significant differences between sites in the duration of use of pulse oximetry, and longer duration of use was associated with later documentation of apnea resolution. In a study in which oximetry was used in addition to standard cardiorespiratory monitoring of seemingly well-convalescent preterm infants, 10% of the infants studied experienced prolonged episodes of hypoxemia without associated bradycardia or prolonged apnea.[11] Although their use was not documented in our study, pneumogram recordings of cardiorespiratory activity of premature infants otherwise considered ready for discharge often reveal abnormalities undetected by standard monitoring techniques.[12,13] It is possible that different approaches to monitoring of convalescent preterm infants might have altered the recording of apneic events and thereby affected discharge timing.

Inter-NICU differences in policies regarding monitor alarm settings and documentation of events might also affect recording of the last apneic or bradycardic episode. No consensus exists about the clinically significant lower limit for bradycardia or the significance of bradycardia without associated apnea in otherwise healthy premature infants approaching discharge to home.[3,14,15] Hospitals are also likely to differ in nursing response and documentation of these events. We included all apneic or bradycardic episodes documented by the nursing staff regardless of their severity in part to account for this potential variability. It is likely that such differences in monitoring and documentation practices between NICUs included in the study sample contributed to the observed variation in timing of apnea resolution.

We did not differentiate between apneic spells that occurred on or off methylxanthine therapy. It is likely that the majority of the last apneic or bradycardic episodes recorded occurred while off methylxanthines because few infants were discharged on this therapy (Table 2). However, differences between NICUs in the PMA when methylxanthines were stopped might have obscured the true timing of the development of mature cardiorespiratory control in some infants and influenced our results.

In the later-discharging NICUs, infants took a longer time to reach full oral feedings and independent thermoregulation in addition to a longer duration of documented apnea or bradycardia episodes (Figs 3 and 4). Although little is known about developmental aspects of feeding behavior, mature cardiorespiratory and feeding behavior often develop in parallel.[3,4] It is not clear whether specific feeding practices can shorten the time course to transition from gavage to full oral feedings.[16,17] However, just as differences in monitoring and documentation might prolong the apparent time to resolution of apnea, some feeding practices might delay the recognition of mature feeding behavior. For example, unit policies that limit oral feedings until infants have reached a specific postnatal weight or PMA might lengthen hospital stays in infants who are otherwise ready for discharge. We speculate that in the absence of a biological explanation, individual NICUs or practitioners with a more conservative approach to feeding, apnea management, or incubator use may prolong hospital stays even in an otherwise healthy population of premature infants.

Because of the observed inter-NICU variability in attainment of mature behavior, we chose to define the margin of safety as the interval between complete physiologic maturity (adequate temperature control, cessation of apnea and bradycardia, and oral feeding) and discharge to home rather than the more standard definition using only the date of last apnea.[4] This definition takes into account variation in NICU practices that might delay or accelerate the recognition of mature feeding or cardiorespiratory behavior in individual hospitals. As expected, we observed inter-NICU differences in the measured margin of safety from the attainment of physiologic maturity to discharge to home (Fig 5). The small variability in the duration of the margin of safety did not have a systematic effect on length of hospital stay. Results were similar when we examined the interval between the last apneic or bradycardic event and discharge. In a 1996 survey of neonatologists regarding apnea management, Darnall et al reported a range of the number of apnea-free days required before discharge to home.[4] Differences were small, however; >70% of the those surveyed required an interval of 5 to 7 days, consistent with the results in our study (Fig 5, Table 2). Our results suggest that the discretionary interval between mature behavior and discharge to home, though slightly different between NICUs, is not a major contributor to differences in discharge timing in the healthy premature population included in this study.

Our results have important implications for discharge guidelines for premature infants. Early discharge programs for premature infants recently have been described, evaluated,[14,18–21] and included in proposed national guidelines for hospital discharge of the high-risk neonate.[22] These programs generally have combined more intensive parental teaching with stronger community-based supports for parents of premature infants who have demonstrated physiologic maturity, regardless of weight or PMA. Several studies have demonstrated the effectiveness of these programs, with significant reductions in length of stay and hospital costs within single institutions.[18,19] Discharge timing of premature infants is a complex process influenced by both medical and nonmedical factors. However, the disparity in the timing of documented physiologic maturity between the NICUs included in our study calls into question whether early discharge programs will be equally effective in different institutions without including guidelines for monitoring and documentation practices.

CONCLUSION

We have shown significant inter-NICU variation in length of hospital stay in a large cohort of healthy premature infants. These differences resulted primarily from variation between hospitals in the documented duration of time to mature feeding behavior and of recurrent apnea or bradycardia events. A description of monitoring techniques and definitions of clinically significant apnea or bradycardia events are essential if national guidelines for the safe discharge of the convalescent premature infant are to effectively reduce length of hospital stay and costs.

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