Comparison of Collaborative Versus Single-Site Quality Improvement to Reduce NICU Length of Stay

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abstract

BACKGROUND: There is unexplained variation in length of stay (LOS) across NICUs, suggesting that there may be practices that can optimize LOS.

METHODS: Three groups of NICUs in the California Perinatal Quality Care Collaborative were followed: (1) collaborative centers participating in an 18-month collaborative quality improvement project to optimize LOS for preterm infants; (2) individual centers aiming to optimize LOS; and (3) nonparticipants. Our aim in the collaborative project was to decrease postmenstrual age (PMA) at discharge for infants born between 27 + 0 and <32 weeks' gestational age by 3 days. A secondary outcome was "early discharge," the proportion of infants discharged from the hospital before 36 + 5 weeks' PMA. The balancing measure of readmissions within 72 hours was tracked for the collaborative group.

RESULTS: From 2013 to 2015, 8917 infants were cared for in 20 collaborative NICUs, 19 individual project NICUs, and 71 nonparticipants. In the collaborative group, the PMA at discharge decreased from 37.8 to 37.5 weeks (P = .02), and early discharge increased from 31.6% to 41.9% (P = .006). The individual project group had no significant change. Nonparticipants had a decrease in PMA from 37.5 to 37.3 weeks (P = .01) but no significant change in early discharge (39.8% to 43.6%; P = .24). There was no significant change in readmissions over time in the collaborative group.

CONCLUSIONS: A structured collaborative project that was focused on optimizing LOS led to a 3-day decrease in LOS and was more effective than individualized quality improvement efforts.

Collaborative quality improvement (QI) approaches have been used to successfully address NICU processes and outcomes of care.[1,2] These projects typically depend on multidisciplinary teams and benefit from collaboration among institutions because strategies for implementation can be learned from many colleagues. What is not well known is whether such collaborative efforts, which are typically resource intensive, achieve more success than individualized QI efforts. Previously, we demonstrated that a multihospital collaborative approach led to more improvement in delivery room resuscitation QI than single-hospital projects.[2]

Reducing length of stay (LOS) for preterm infants is another complex, multidisciplinary effort that may benefit from intensive QI efforts. Very low birth weight (VLBW) infants account for substantial hospital days

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across the United States. In estimates, it is suggested that 55 947 VLBW infants were born in the United States in 2014.[3] The median LOS of initial NICU hospitalization is 46 days for an infant with a birth weight of 1000 to 1500 g and 79 days for an infant with a birth weight of <1000 g.[4] Costs associated with these admissions, financially to the health care system and emotionally to families, are significant.[5,6]

Recent studies reveal substantial variation in LOS across NICUs.[4,7] Although variation from risk factors for VLBW LOS have been addressed in risk adjustment models, it has not been accounted for fully. Variation in LOS is likely to be driven at least partially by variation in practice within and between NICUs. Some practices and policies may contribute to longer LOS without providing benefit.

Our objective was to assess the effectiveness of a collaborative QI project designed to optimize LOS for preterm NICU patients. By "optimizing" LOS, we intended to institute practices that would decrease overall LOS safely without leading to unintended consequences such as readmissions.

METHODS

Context

We aimed to compare a collaborative QI model to a single-site QI model (NICU QI version 2.0) when implementing an evidence-based practice bundle for optimizing LOS. The California Perinatal Quality Care Collaborative (CPQCC) collects clinical data prospectively for infants born at 138 California hospitals by using an expanded version of the Vermont Oxford Network (VON) database.[8,9] Participation in collaborative QI was offered to all CPQCC members and was open to the first hospitals that responded until spaces were filled. Remaining hospitals were offered participation in NICU QI version 2.0. The Stanford University Institutional Review Board approved the study.

Intervention

The first 25 NICUs that signed up to participate in the project formed the collaborative QI group and followed a model similar to that outlined by the Institute for Healthcare Improvement.[10] An expert panel developed an evidence-based change package, developed a measurement grid, led monthly webcasts in which members shared progress reports, and participated in e-mail listserv discussions. The collaborative QI group committed to participating in 3 face-to-face sessions over 12 months. During the middle of that year, it was decided to extend the length of the collaborative project by 6 months to a total of 18 months. Because this was optional, 5 NICUs decided to stop at the original 12-month mark (June 2014). For the main analyses, these 5 NICUs were excluded.

Comparison Groups

NICU QI 2.0

Our NICU QI model has been described previously.[2] On the basis of feedback from the previous NICU QI cohort (NICU QI 1.0), we evolved the model to do the following: (1) include names and contact information for all participating sites, and (2) provide access to a password-protected data repository for entry of outcome, process, and balancing metrics that were graphed over time and visible to all NICU QI 2.0 participants. As in the previous NICU QI model, NICU QI 2.0 centers were given the same change package and metrics grid as collaborative QI sites and were instructed to implement all interventions, report the same metrics monthly, and to meet with local QI experts at least quarterly. NICU QI 2.0 centers were encouraged to seek practical assistance from internal QI experts and, if necessary, outside content experts.

Nonparticipants

This group included CPQCC members that chose not to participate in either the collaborative or NICU QI 2.0 group.

Aim Statement

Our aim in the CPQCC Optimizing LOS in the NICU QI Collaborative was to decrease median postmenstrual age (PMA) at discharge for eligible infants by 3 days, within the time frame of January 2013 to June 2013 (baseline period) and the intervention time frame. The intervention time frame was originally assigned to be from July 2013 to June 2014 but was later extended to December 2014.

Inclusion criteria were as follows: infants born at 27 + 0 weeks' gestational age up to 31 + 6 or 7 weeks; inborn or outborn transferred in to the member NICU within 2 days after delivery, with maximum time away from the NICU of ≤48 hours (ie, at another NICU); and discharged from the hospital directly from the site. Patients who died or had major congenital anomalies were excluded. Gestational age was the best available estimate in weeks and days. When sources disagreed, obstetric measures based on the last menstrual period, obstetrical parameters, or prenatal ultrasound as recorded in the maternal chart took precedence over the neonatologist's estimate.

Change Package

The change package developed by the expert panel was focused on 3 main areas that could plausibly impact LOS for preterm infants: standardizing feeding approaches, standardizing discharge planning, and standardizing the definition, workup, and treatment approach to apnea, bradycardia, and oxygen desaturation events (Table 1).

TABLE 1 Change Package for the Optimizing LOS Collaborative QI Project

1. Standardize nutritional best practices on the basis of physiologic maturity rather than gestational age criteria. Essential practice components include the following:
   1.1 Standardize feeding initiation and advancement for optimal growth
   1.2 Standardize the transition to oral feedings on the basis of physiologic maturity, not gestational age or wt (ideally on the basis of feeding readiness score)
2. Create a discharge planning pathway with clearly identified time points for critical assessments focused on the following components:
   2.1 Create and use a visible discharge checklist that allows documentation of discharge milestones
   2.2 Standardize the timing of infant discharge on the basis of infant medical status, infant functioning, and caregiver competence (rather than arbitrarily chosen or PMA)
3. Standardize the approach to apnea, bradycardia, and desaturation events as follows:
   3.1 Standardize the definition of a "CSCE"
   3.2 Establish a standard approach to care (as demonstrated by standard order sets, checklists, and/or protocols) when a CSCE occurs, including the following: establishing a standard for when treatment is necessary, when treatment should be discontinued, the duration of time between the last CSCE and discharge, and when home monitoring (where available) is appropriate

In standardizing practices, teams at each NICU are encouraged to create their own standards; suggestions and recommendations are provided from other sites to help, but a collaborative-wide standard is not established

Primary references for potentially better practices

1. Nutritional support of the VLBW infant, CPQCC toolkit, rev. 2008
2. Discharge planning management, VON QI toolkit 2009

CSCE, clinically significant cardiopulmonary event.

Study of the Intervention

Measures

The primary outcome was PMA at discharge. The PMA was calculated as gestational age at birth (in days) plus initial LOS until discharge from the hospital.

There were 2 secondary outcomes. The first was LOS at discharge, calculated as the LOS in the NICU until discharge from the hospital. For infants readmitted to the NICU (after transfer to another NICU for 48 hours or less but not yet to home), the sum of the LOS until discharge from the hospital, including the stay at the other NICU, was calculated.

Second was the percentage of eligible infants discharged from the hospital before 36 + 5 weeks' PMA, which we termed "early PMA at discharge." This cutoff was used because this was the median age at discharge at baseline for all of the groups combined.

The primary balancing measure considered in analysis was readmissions within 72 hours of discharge. The CPQCC does not collect comprehensive data on readmissions from all member hospitals. Collaborative QI members were asked to track readmission via routine follow-up phone calls completed 72 hours or later after discharge.

Data Analysis

The following periods were defined for analysis of change over time, generally corresponding to the intervention time line:

- period 0 (baseline): January 2013 to June 2013;
- period 1: July 2013 to December 2013;
- period 2: January 2014 to June 2014;
- period 3: July 2014 to December 2014;
- period 4 (post intervention): January 2015 to June 2015; and
- period 5 (post intervention): July 2015 to December 2015.

The collaborative project formally ended in December 2014; therefore, periods 4 and 5 represent periods in which we could assess sustainability of the project over a 12-month period.

Participating NICUs collected data specifically for the project. However, for the purpose of this study, whenever possible, we used CPQCC data that are prospectively collected by trained data abstractors for all CPQCC centers, not just those that participated in QI. The CPQCC collected clinical data prospectively for all of the eligible patients for this study by using an expanded version of the VON database.[11,12]

For each collaborative QI NICU, we created individuals and moving range (XmR) charts for PMA at discharge from the hospital. The centerline and control limits were derived by using data from all infants in the NICU during the study period. We used 3 tests for special cause variation: outside the control limits, 9 points in a row in a zone, and 6 points in a row steadily increasing or decreasing.

To compare the 3 groups of NICU in aggregate, we combined data across units for the collaborative QI, NICU QI, and nonparticipant groups. For PMA at discharge and LOS at discharge, lognormal mixed models were used, accounting for clustering by hospital of care. Outcomes were risk adjusted for weeks' gestational age, weeks' gestational age squared, small for gestational age, multiple gestation, Apgar score at 5 minutes, race and/or ethnicity, sex, outborn status, and prenatal care. These methods were based on the model used by the CPQCC for risk adjustment in preparing reports for member NICUs. In this model, log (PMA at discharge) or log (LOS) was used as the dependent variable, and the predicted outcome values were transformed back in the original scale to obtain adjusted average PMA at discharge and LOS (geometric mean). The geometric mean is similar in value to the median and is a robust estimate for PMA or LOS, reducing the influence of the outlier values with very long LOS.

For the outcome of the percentage of patients having an early PMA at

TABLE 2 Characteristics of Hospitals

Hospitals	Collaborative QI	NICU QI	Nonparticipants	*P*
n[a]	20	19	71	—
AAP level[b], %				
2	10.0	5.3	5.8	.12
3	55.0	78.9	84.1	
4	35.0	15.8	10.1	
Hospital type, %				
District	5.0	5.3	5.7	.82
For profit, private	10.0	10.5	12.9	
Nonprofit private	80.0	68.4	62.9	
Public, city or county	0.0	15.8	11.4	
University of California	5.0	0.0	7.1	
NICU volume, %				
Lowest quartile	20.0	31.6	28.2	.01
Second quartile	20.0	26.3	26.8	
Third quartile	10.0	10.5	32.4	
Highest quartile	50.0	31.6	12.7	

P values reflect χ^2 test by hospital group. —, not applicable.

[a] Data on 5 centers that participated in the collaborative QI for only part of the study period are not shown.

[b] AAP levels of neonatal care, from AAP Committee on Fetus & Newborn. Levels of Neonatal Care. *Pediatrics*. 2012;130(3): 587–597.

TABLE 3 Characteristics of Patients

Patients	Collaborative QI	NICU QI	Nonparticipants	*P*
n	2394	1635	4888	—
Birth wt in g, %				
<750	2.2	2.1	2.2	.83
750–999	11.3	11.6	10.5	
1000–1249	24.7	25.4	24.3	
1250–1499	28.4	28.8	28.8	
1500+	33.4	32.1	34.1	
Gestational age in wk, %				
27	12.0	11.7	11.6	.23
28	15.0	14.9	14.7	
29	17.7	18.2	17.8	
30	22.4	25.0	24.0	
31	32.9	30.2	31.9	
Maternal age in y, %				
<20	6.1	5.7	5.5	<.001
20–24	14.5	19.6	15.2	
25–29	21.9	23.4	23.7	
30–34	29.9	27.0	27.2	
35+	27.6	24.3	28.4	
Race and/or ethnicity, %				
African American	11.1	12.9	10.5	<.001
Hispanic	46.3	50.1	43.9	
White	26.2	25.4	29.6	
Asian	14.4	8.4	13.4	
Other	1.9	3.3	2.7	
Multiple gestation, %	25.6	27.0	27.3	.23
Cesarean delivery, %	70.4	70.8	70.9	.91
Small for gestational age, %	14.9	14.0	14.8	.86
Antenatal steroids, %	89.8	87.3	88.3	.05
Male sex, %	54.3	53.3	54.1	.72
Outborn, %	12.4	14.8	6.9	<.001

P values reflect χ^2 test by hospital group. —, not applicable.

discharge, we used hierarchical logistic regression, with risk adjustment according to the same variables for the primary outcome listed above.

The assessment of overall trend in the outcomes was assessed by the *P* value generated by testing the interaction of time period and study group.

For analyses in which we were evaluating hospital outcomes, we excluded low-volume centers that cared for <15 eligible patients during the whole study period (14 centers from the nonparticipant group, none from the collaborative QI or NICU QI 2.0 groups).

RESULTS

One hundred and ten CPQCC member hospitals (20 collaborative, 19 NICU QI 2.0, and 71 nonparticipants) were eligible. During the study period, 8917 eligible infants were cared for across these hospitals (collaborative QI hospitals: *n* = 2394; NICU QI 2.0: *n* = 1635; and nonparticipants: *n* = 4888). The hospitals were similar in regard to the distribution of American Academy of Pediatrics (AAP) neonatal level of care and hospital type, but the collaborative QI group included more higher-volume hospitals (Table 2). There were 14 CPQCC hospitals excluded, all in the nonparticipant group for not meeting the minimum number of 15 eligible infants. Five collaborative QI hospitals were excluded because of not completing the 18-month intervention time frame.

Patients cared for across the 3 groups had similar distributions of birth weight and gestational age. There were differences in the distribution of maternal age and race and/or ethnicity across the 3 groups. The collaborative QI and NICU QI groups had higher proportions of outborn infants than the nonparticipant group (Table 3).

For the 20 NICUs in the collaborative QI group, XmR control charts varied in their trajectories. Four NICUs had evidence of special cause variation during the intervention and sustainment phases (example control chart shown in Fig 1A), whereas 10 NICUs did not have clear evidence of change throughout the study period (no special cause variation, example control chart shown in Fig 1B),

and 4 NICUs had initial patterns of improvement but lacked longer-term sustainment (example control chart shown in Fig 1C); charts were not produced for 2 NICUs because they had a low number of eligible patients.

In adjusted analyses, the collaborative QI hospitals had a decrease in adjusted PMA at discharge, from 37.8 weeks to 37.5 weeks and a decrease in adjusted LOS, from 52.9 days to 50.0 days over the study period (Table 4). Early PMA at discharge increased from 31.6% of eligible patients at baseline to 41.9% of patients by period 5. For all of these 3 outcome measures, the collaborative QI group had significant improvement over time: for adjusted PMA at discharge, $P = .04$; for adjusted LOS, $P = .006$; and for early PMA at discharge, $P = .02$. The NICU QI group did not have significant changes in any of the outcome measures over time. The nonparticipants had significantly lower PMAs at discharge and LOSs in periods 1 and 5 compared with baseline, but there was not a significant trend overall toward improvement.

Data on the balancing measure of readmissions after discharge from the hospital after initial hospitalization were collected only by the collaborative QI group. The total numbers of readmissions reported were 2 across the 20 collaborative QI NICUs in the baseline period (0.5%): 5 in period 1 (1.3%), 3 in period 2 (0.8%), 6 in period 3 (1.4%), 4 in period 4 (1.0%), and 0 in period 5.

DISCUSSION

Compared with individual site QI and nonparticipants, we found that the collaborative QI group had the most success in reducing LOS, reducing median PMA at discharge by 3 days, and had the most success in increasing the proportion of infants that went home before 36 + 5 weeks'

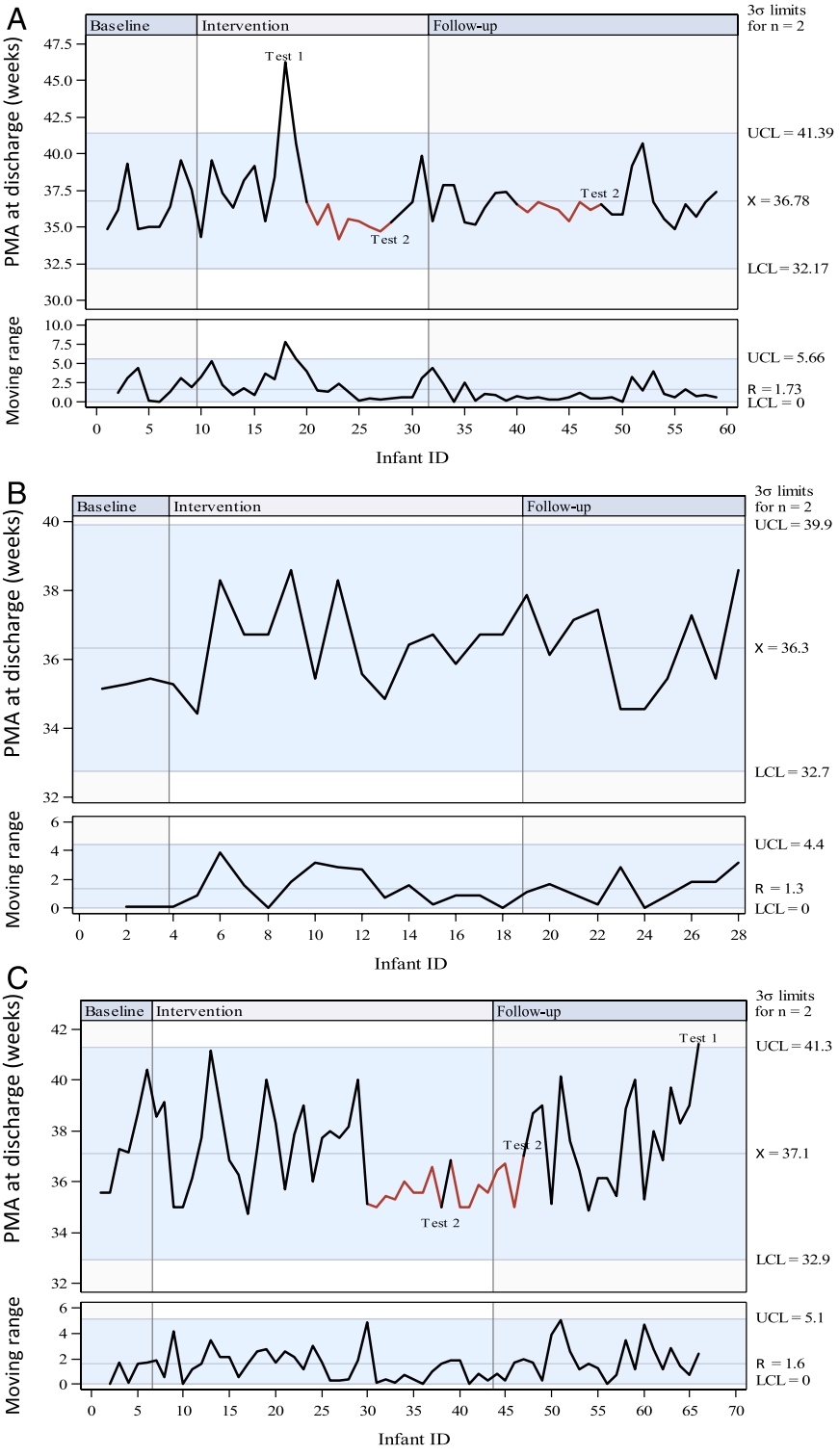

FIGURE 1

Three examples of XmR charts of collaborative QI group NICUs. (A) A NICU that showed consistent improvement. (B) A NICU that did not have special cause variation. (C) A NICU that had some improvement but lacked sustainment. ID, identification; LCL, lower control limit; UCL, upper control limit.

TABLE 4 Outcomes by Study Period and Study Group

Group	Collaborative QI	*P*	NICU QI	*P*	Nonparticipants	*P*
Adjusted PMA at discharge, wk						
Baseline	37.8	—	37.5	—	37.5	—
Period 1	37.8	.79	37.6	.49	37.3	.05
Period 2	37.5	.02	37.5	.74	37.4	.34
Period 3	37.5	.06	37.6	.55	37.4	.17
Period 4	37.5	.02	37.5	.94	37.4	.14
Period 5	37.5	.02	37.4	.61	37.3	.01
Adjusted LOS, d						
Baseline	52.9	—	50.9	—	50.4	—
Period 1	52.2	.51	51.9	.40	49.0	.03
Period 2	50.1	.005	50.1	.45	49.9	.46
Period 3	50.3	.008	51.5	.60	49.5	.16
Period 4	50.3	.008	49.7	.29	49.6	.20
Period 5	50.0	.004	50.2	.52	48.8	.02
Adjusted early PMA at discharge, %						
Baseline	31.6	—	38.6	—	39.8	—
Period 1	36.3	.19	34.7	.38	44.9	.38
Period 2	39.6	.03	39.5	.84	39.7	.84
Period 3	42.5	.003	34.5	.37	42.3	.37
Period 4	42.8	.002	45.1	.17	40.2	.17
Period 5	41.9	.006	44.0	.24	43.6	.24

P values represent comparisons with baseline for each group. —, not applicable.

gestational age, from 31.6% to 41.9%. The goal to use QI for optimizing LOS and creating benchmarks for early hospital discharge is not a new concept. Brooten et al[13] described a program back in 1986 with the principle of readiness for discharge and supportive measures for earlier discharge. Following up on this work, Wirtschafter et al[14] applied similar principles in 1994 to reduce variation across a group of California's NICUs belonging to Kaiser Permanente.

As we had seen in a previous study of QI implementation, an individual NICU QI approach did not result in the gains seen in the collaborative QI group.[2] On the basis of the findings of that previous project, we added data sharing and transparency of participating sites to create our NICU QI 2.0 approach. Despite these 2 additions, identified as likely to be helpful by sites in the NICU QI 1.0 model, there was not a significant improvement in LOS across these 19 NICUs. Presumably, collaborating in ways other than data sharing and site transparency allowed the collaborative QI group to advance in their QI efforts more than the other 2 groups.

It is worth noting that on average, the units that joined the collaborative had longer LOSs and would have had more opportunities to improve. For NICUs in the other 2 groups that may have already had better performance, there would have been more difficulty in reducing LOS. In that respect, perhaps the collaborative group attracted participants that had the most room to improve. Furthermore, we found that among the collaborative QI group, there was not a consistent trend of improvement for each NICU. Some NICUs had consistent improvement over the study period, whereas others had little evidence of change, and some showed initial change but did not have sustained improvement. Because this demonstrates heterogeneity of those NICUs joining the QI effort, further steps to investigate for whom the intervention worked better than others will help to inform future work in collaborative QI. With our experience, we argue for designing collaborative QI structures that would entail multiple cycles, in which lessons learned from the antecedent cycle are used to test subsequent hypotheses.

Although costs will vary, if we estimate the average daily cost of NICU hospitalization to be $3000,[15] with a 3-day reduction in NICU stay totaling up to $9000 in savings, a typical NICU caring for 50 similar preterm infants could reduce costs by $450 000 annually. When considering the population perspective with ~6500 eligible infants, up to $58.5 million annually could be saved across the state of California. Considering that the government is often the insurer for many of these neonates, reducing LOS even by a few days could ultimately save millions of dollars for the state of California. Furthermore, shifting financial incentives may align with this goal of limiting intensive care hospitalizations and shifting use to lower-cost outpatient care.[16]

The focus for optimizing LOS in the QI projects was preterm infants. A collaborative QI project of the VON that was focused on infants born with neonatal abstinence syndrome resulted in a decrease in the median LOS by 2 days.[17] Although 2 to 3 days is a small proportion of a prolonged hospitalization, it can potentially be meaningful for families eager to transition to home and also reduce health care costs when applied to a large population.

There were several study limitations. Because participant group assignments were not randomly assigned, differences in population characteristics could affect our conclusions. The types of NICUs that participated in the collaborative project differed in level of care and volume compared with nonparticipants (Table 2). The baseline LOS of the collaborative QI group was longer than the other 2 groups. Additionally, the groups may have differed in their past

experiences and training in QI. Analysis revealed no difference in birth weight or gestational age at birth across the groups; however, there were differences based on maternal age, race and/or ethnicity, and proportion of outborn infants. These variables were included in risk adjustment models. We did not actively collect process metrics or balancing measures for the NICU QI or nonparticipant populations. Finally, we were limited in our ability to comprehensively track either adherence to the practice guidelines or the balancing measure of readmissions to the NICU after initial hospital discharge because these variables are not routinely collected by CPQCC. Anecdotally, we did not see an increase in readmissions in the collaborative QI group, and results from follow-up phone calls to families did not reveal an increased trend of readmissions. For those readmitted, we did not collect reason for readmission. Ultimately, this is a measure that should be tracked over time when there is a concerted effort to reduce LOS.

A minimal LOS may not be the best strategy for improving clinical outcomes or even costs.[18] Our aim in the CPQCC QI project was not to minimize LOS excessively but to use localized standardization of practice to improve overall quality of care, with the expected goal being reduction of LOS.

CONCLUSIONS

We further advance the science of QI because with our findings we add to the evidence base that a structured collaborative QI effort among institutions continues to be more effective than individual QI efforts, even when these sites have access to similar tools provided to the collaborative. In our study, we demonstrate that a structured collaborative QI effort to locally standardize processes related to nutrition, discharge, and apnea and/or bradycardia management for preterm infants in NICUs can safely decrease LOS. However, not all NICUs in the collaborative QI group improved, which suggests that a one-size-fits-all approach may not be optimal. Continued research on models with effective support structures for individual sites to improve quality outcomes without the resource intensity of structured collaboratives is warranted.

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ABBREVIATIONS

AAP: American Academy of Pediatrics
CPQCC: California Perinatal Quality Care Collaborative
LOS: length of stay
PMA: postmenstrual age
QI: quality improvement
VLBW: very low birth weight
VON: Vermont Oxford Network
XmR: individuals and moving range

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