Implementation Methods for Delivery Room Management: A Quality Improvement Comparison Study

WHAT’S KNOWN ON THIS SUBJECT: Quality improvement (QI) studies generally do not account for concurrent trends of improvement and it is difficult to distinguish the impact of a multihospital collaborative QI project without a contemporary control group.

WHAT THIS STUDY ADDS: A multihospital collaborative QI model led to greater declines in hypothermia and invasive ventilation rates in the delivery room compared with an individual NICU QI model and NICUs that did not participate in formal QI activities.

BACKGROUND: There is little evidence to compare the effectiveness of large collaborative quality improvement versus individual local projects.

METHODS: This was a prospective pre-post intervention study of neonatal resuscitation practice, comparing 3 groups of nonrandomized hospitals in the California Perinatal Quality Care Collaborative: (1) collaborative, hospitals working together through face-to-face meetings, webcasts, electronic mailing list, and data sharing; (2) individual, hospitals working independently; and (3) nonparticipant hospitals. The collaborative and individual arms participated in improvement activities, focusing on reducing hypothermia and invasive ventilatory support.

RESULTS: There were 20 collaborative, 31 individual, and 44 nonparticipant hospitals caring for 12,528 eligible infants. Each group had reduced hypothermia from baseline to postintervention. The collaborative group had the most significant decrease in hypothermia, from 39% to 21%, compared with individual hospital efforts of 38% to 33%, and nonparticipants of 42% to 34%. After risk adjustment, the collaborative group had twice the magnitude of decrease in rates of newborns with hypothermia compared with the other groups. Collaborative improvement also led to greater decreases in delivery room intubation (53% to 40%) and surfactant administration (37% to 20%).

CONCLUSIONS: Collaborative efforts resulted in larger improvements in delivery room outcomes and processes than individual efforts or nonparticipation. These findings have implications for planning quality improvement projects for implementation of evidence-based practices. Pediatrics 2014;134:e1378–e1386

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KEY WORDS
quality improvement, collaborative, neonatal resuscitation, very low birth weight

ABBREVIATIONS
QI—quality improvement
CPAP—continuous positive airway pressure
CPQC—California Perinatal Quality Care Collaborative
IHI—Institute for Healthcare Improvement
NRP—Neonatal Resuscitation Program
VLBW—very low birth weight

Dr Lee conceptualized and designed the study, and drafted the initial manuscript; Dr Powers conceptualized and designed the study, coordinated and supervised the study, and critically reviewed the manuscript; Dr Bennett contributed to the study design, developed statistical models for the study, coordinated and supervised data analyses, and critically reviewed the manuscript; Drs Finer and Halamek contributed to study design, served on the expert panel that guided the collaborative quality improvement arm, and critically reviewed the manuscript; Ms Nisbet contributed to study design, served on the expert panel that guided the collaborative quality improvement arm, and critically reviewed the manuscript; Drs Crockett, Drs Chance and Kurtin, Mr Blackney, and Ms von Köhler contributed to the intervention design, served on the expert panel that guided the collaborative quality improvement arm, and critically reviewed the manuscript; Dr Sharek contributed to study design, led the expert panel of the quality improvement arm, coordinated and supervised the study team, and critically reviewed the manuscript; and all authors approved the final manuscript as submitted.

(Continued on last page)
Recent updates of the Neonatal Resuscitation Program (NRP) and other evidence emphasize the importance of teamwork and safety climate in effective implementation of complex tasks. Adopting evidence-based changes has been enhanced by participation in collaborative quality improvement (QI) projects, where changes are bundled together and implemented by teams from different centers sharing common strategies.

Collaborative QI, based on the Institute for Healthcare Improvement’s (IHI) model, has been successful in settings such as the California Perinatal Quality Care Collaborative (CPQCC). This model brings together teams from different institutions, providing structured learning with face-to-face meetings, Web-based discussions, electronic mailing lists, expert panel access, and unblinded outcome and process data display, with incremental learning through reporting of successes, barriers, and lessons learned.

In 2010, CPQCC planned a collaborative QI project to improve management of high-risk deliveries, with a best practice bundle constructed from published evidence and guidelines for temperature and respiratory management for very low birth weight (VLBW; birth weight <1500 g) infants. Specific interventions included strategies to avoid hypothermia; establishment of lung volume in the least-invasive manner; and supporting teamwork with checklists, briefings, and debriefings.

Although the collaborative model has been successful, significant barriers to participation occur, including costs, personnel availability, and limitations on number of sites. Therefore, CPQCC constructed a novel single-site QI model (NICU QI) not requiring interaction with other sites. In this arm, the same bundle was provided, but implementation was directed by individual centers.

The purpose of this study was to prospectively test 2 different QI methods (collaborative QI and NICU QI) against a third group of nonparticipants. This comparison would minimize the influence of biases frequently seen in QI study designs that compare the intervention over time against baseline data without controls. A comparison group of nonparticipants can account for secular, concurrent trends in practices. Furthermore, comparison with a group also pursuing QI with a differing strategy would limit selection bias of participant motivation. Our hypothesis was that there would be incremental increases in improvement from nonparticipants to NICU QI to collaborative QI.

**METHODS**

**Study Design and Setting**

This was a prospective longitudinal cohort study of a collaborative QI model compared with a single-site QI model (NICU QI) and a nonparticipant population when implementing an evidence-based practice bundle for delivery room management. The CPQCC collects clinical data prospectively for infants born at 132 California hospitals by using an expanded version of the Vermont Oxford Dataset. Participation in collaborative QI was offered to all CPQCC centers and open to the first hospitals that responded until spaces were filled. Remaining hospitals were offered participation in NICU QI. The institutional review board at Stanford University reviewed and approved a waiver of consent for this project.

**Study Groups**

**Collaborative QI**

The collaborative QI group adhered to the IHI model previously used by CPQCC. An expert panel developed an evidence-based change package and corresponding metrics. The group participated in 3 face-to-face learning sessions: at collaborative launch, 4 months, and 12 months. Other components included monthly webcasts to share progress and barriers, an electronic mailing list, submission of unblinded outcome and process data to a Web-enabled database exclusively for members, and expert panel guidance. The entire group’s data were presented in monthly meetings and each center had real-time data access at all times. A key aspect of implementation involved teamwork training in a readiness bundle, including pre-resuscitation checklist, briefing, and debriefing.

**Nonparticipant Group**

This group included CPQCC hospitals that were not in the other groups. They were not required to collect data other than that already being collected for CPQCC.

**NICU QI**

The elements of the NICU QI group were based on a design intended to provide centers with the change package and framework for implementation without interaction with other centers. NICU QI centers were given the same change package and metrics grid as Collaborative QI and were instructed to implement all interventions, report the same metrics monthly via electronic forms (not visible to other sites), and to meet with local QI experts at least quarterly. NICU QI centers were encouraged to seek practical assistance from internal QI experts and, if necessary, outside content experts. Table 1 lists key characteristics distinguishing the Collaborative and NICU QI groups.
TABLE 1  Characteristics of Intervention Models Comparing Collaborative Versus NICU QI Groups

<table>
<thead>
<tr>
<th>Component</th>
<th>CPQCC QI Collaborative Model</th>
<th>CPQCC NICU QI Model</th>
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<tbody>
<tr>
<td>Technical knowledge</td>
<td>Expert Panel uses Toolkit to draft charter and change package. Expert Panel devotes 1 day plus follow-up discussions to help NICUs develop much of the charter and change package, then facilitates finalization of these with the NICUs. Use of CPQCC Toolkit with user friendly 1- to 2-page change package.</td>
<td>A basic understanding of QI principles (view training module online and participate in kick-off webinar or workshop with Local QI Expert, defined as a person at the hospital trained in QI methods). QI Expert helps NICU project team create local AIM statement. AIM Statement sent into CPQCC.</td>
</tr>
<tr>
<td>QI principles</td>
<td>QI Experts from Expert Panel provide teaching on QI principles at initial face-to-face Learning Session and reinforce teaching on monthly calls and each face-to-face Learning Session.</td>
<td>Monthly report out by each NICU; extensive data collection with downloadable graphs and reports; entry into extranet; expert assistance with entering data and understanding graphs; QI Expert(s) graph collaborative results.</td>
</tr>
<tr>
<td>AIM statement</td>
<td>Expert Panel devotes 1 day plus follow-up discussions to develop much of the Collaborative AIM statement then facilitates finalization of the AIM statement with the NICUs. NICUs develop individual AIM statements.</td>
<td>Primary outcome data sent into CPQCC monthly.</td>
</tr>
<tr>
<td>Outcome data</td>
<td>Monthly report out by each NICU; time for sharing and asking one another questions; data for the collaborative reviewed in detail each month.</td>
<td>Process Metrics sent into CPQCC monthly.</td>
</tr>
<tr>
<td>Process metrics</td>
<td>Monthly report out by each NICU; extensive data collection with downloadable graphs and reports; entry into extranet; expert assistance with entering data and understanding graphs; QI Expert(s) graph collaborative results.</td>
<td>Quarterly local staff meetings (kick-off and 3 other meetings) at site to review data/interventions/barriers; Expert participates in these meetings.</td>
</tr>
<tr>
<td>Meetings</td>
<td>3 face-to-face, full-day meetings, all 3 Learning Sessions with full Expert Panel. Monthly Web-based/teleconference meetings (60–90 min) with full Expert Panel and presentation each month by 1 Expert; report out by each NICU; time for sharing and asking one another questions; data for the collaborative reviewed in detail each month.</td>
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temperature recorded on NICU admission and must be recorded within 1 hour after birth. Temperature was missing for 1% of records. Rates were compared by using the $\chi^2$ test.

Multivariable analyses were conducted at the patient level. The main predictor variable was time period. We accounted for the following risk adjustment variables: NICU-eligible patient volume (categorized in terciles), birth weight, gender, maternal age, race, multiple gestation, small for gestational age, congenital anomaly, receipt of antenatal steroids, and mode of delivery. Birth weight and small for gestational age were used rather than gestational age alone as predictors along with the hospital of care being accounted for as a random effect, by using methods similar to those described previously.\textsuperscript{7,28,29}

We determined the statistical significance of the observed heterogeneity of outcome change over time by incorporating study period and study group interactions. A $P < .05$ for the interaction term would indicate evidence of study group effect.

**RESULTS**

Ninety-five CPQCC member hospitals (20 collaborative QI, 31 NICU QI, 44 nonparticipant hospitals) were eligible. In these 95 hospitals, there were 12,528 eligible inborn infants (collaborative QI hospitals, $n = 4,625$; NICU QI, $n = 3,229$; nonparticipants, $n = 4,674$). There were 37 CPQCC hospitals excluded (collaborative QI 4, NICU QI 4, nonparticipants 29) for not meeting the minimum number of 10 eligible infant deliveries for each of all 3 study periods. Baseline characteristics by group are shown in Table 3. For the collaborative QI group, the 3 face-to-face Learning Sessions had an average of 105 participants.

All 3 groups had decreased hypothermia rates over time (Fig 1A). The collaborative QI group had the largest decrease in prevalence of hypothermia from 39.2% at baseline, 27.7% during the intervention period, and 20.7% during the postintervention period ($P < .0001$ compared with baseline for intervention and postintervention). The NICU QI and nonparticipant groups also had decreased prevalence of hypothermia (Fig 1A). Hyperthermia increased in the collaborative QI group from 5.9% in the baseline period to 8.8% in the postintervention period ($P = .0015$), but did not change in other groups (Fig 1B).

CPAP use (Fig 1C), and CPAP without intubation (Fig 1D) increased from baseline to postintervention for all groups. Delivery room surfactant decreased for collaborative QI (36.6% baseline to 19.5% postintervention, $P < .0001$) and NICU QI (18.8% baseline to 12.4% postintervention, $P < .0001$), but did not change in nonparticipants (17.6% baseline to 16.1% postintervention, $P = .26$, Fig 1E). Delivery room endotracheal intubation decreased for collaborative QI (55.3% to 39.6%, $P < .0001$) and NICU QI (43.8% to 36.2%, $P = .0003$) but not for nonparticipants (43.3% baseline to 40.0% postintervention, $P = .06$, Fig 1F).

In mixed effects multivariable logistic regression analyses, there was general improvement across all groups in temperature and respiratory management (Fig 2). However, there was a larger degree of improvement for collaborative QI compared with NICU QI and nonparticipants, in reduction of hypothermia, intubation, and surfactant use. The greater improvement seen in the collaborative QI group compared with the NICU QI and nonparticipant groups was significant based on test for homogeneity and by nonoverlapping confidence intervals for the collaborative QI group compared with the other groups. The NICU QI group had a more significant improvement in reduction of surfactant use compared with nonparticipants.

For both unadjusted rates and in multivariable models, there was no change in cardiac compressions, epinephrine use, or pneumothorax across time periods for all groups.

Of the collaborative QI group, 90% of NICUs saw an improvement in hypothermia rates from baseline to postintervention (defined as any decrease in hypothermia rate), compared with 61% of NICU QI centers and 59% of nonparticipant centers. CPAP use increased for 90% of collaborative QI, 71%...
TABLE 3  Baseline Characteristics by Study Group

<table>
<thead>
<tr>
<th></th>
<th>Collaborative QI</th>
<th>NICU QI</th>
<th>Nonparticipants</th>
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<tbody>
<tr>
<td><strong>n hospitals</strong></td>
<td>20</td>
<td>31</td>
<td>44</td>
</tr>
<tr>
<td>Hospital level of care,* %</td>
<td>74</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>IA/IB</td>
<td>20</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>IIIA/IIIB</td>
<td>50</td>
<td>87</td>
<td>86</td>
</tr>
<tr>
<td>IIIC</td>
<td>30</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>No. of NICU beds (SD)</td>
<td>43 (21)</td>
<td>25 (12)</td>
<td>25 (14)</td>
</tr>
<tr>
<td>No. of live births (SD)*</td>
<td>4569 (2009)</td>
<td>2902 (1164)</td>
<td>2862 (1098)</td>
</tr>
<tr>
<td>Teaching hospitals, %</td>
<td>21</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td><strong>n patients</strong></td>
<td>1624</td>
<td>1099</td>
<td>1589</td>
</tr>
<tr>
<td>Birth weight, g (SD)</td>
<td>1099 (303)</td>
<td>1092 (300)</td>
<td>1092 (305)</td>
</tr>
<tr>
<td>Gestational age, d (SD)</td>
<td>202 (20)</td>
<td>201 (20)</td>
<td>201 (20)</td>
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<tr>
<td>Maternal age (SD)</td>
<td>29 (7)</td>
<td>29 (7)</td>
<td>30 (7)</td>
</tr>
<tr>
<td>No prenatal care, %</td>
<td>2.0</td>
<td>3.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Race/ethnicity, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>29.9</td>
<td>29.2</td>
<td>23.1</td>
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<tr>
<td>Hispanic</td>
<td>40.4</td>
<td>42.5</td>
<td>50.4</td>
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<tr>
<td>Black</td>
<td>13.5</td>
<td>13.6</td>
<td>13.7</td>
</tr>
<tr>
<td>Asian</td>
<td>13.1</td>
<td>13.4</td>
<td>9.8</td>
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<tr>
<td>American Indian</td>
<td>0.4</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>Other</td>
<td>2.6</td>
<td>0.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Multiple gestation, %</td>
<td>30.0</td>
<td>26.5</td>
<td>26.3</td>
</tr>
<tr>
<td>Cesarean delivery, %</td>
<td>76.8</td>
<td>76.4</td>
<td>74.9</td>
</tr>
<tr>
<td>Hypothermia, %</td>
<td>39.2</td>
<td>75.4</td>
<td>42.4</td>
</tr>
<tr>
<td>Hypothermia, %</td>
<td>5.9</td>
<td>4.5</td>
<td>3.4</td>
</tr>
<tr>
<td>CPAP in DR, %</td>
<td>56.7</td>
<td>45.5</td>
<td>38.2</td>
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<tr>
<td>CPAP, not intubated in DR, %</td>
<td>31.0</td>
<td>31.0</td>
<td>24.7</td>
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<td>Surfactant in DR, %</td>
<td>36.6</td>
<td>18.8</td>
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<tr>
<td>Endotracheal intubation in DR, %</td>
<td>53.3</td>
<td>43.8</td>
<td>43.3</td>
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*Hospital level of care is denoted based on the categorization from the American Academy of Pediatrics during the study period. Number of live births were all births at the hospital during 2010.

for NICU QI, and for 64% of nonparticipants. Ventilation by endotracheal tube decreased for 75% of collaborative QI centers, 68% of NICU QI centers, and 64% of nonparticipants. A similar number of centers across the 3 groups (65% to 70%) had an increase in hyperthermia rates.

**DISCUSSION**

Our goals were to (1) compare the effectiveness of the IHI's collaborative QI model with a single-site QI model in which both groups were supplied with the same change package, metrics grid, and data-tracking requirements over the same time frame, and (2) to compare both of those models to a nonparticipant group. For the first goal, the difference in the 2 models was the participation of the collaborative QI sites in a “community of practice” in which each site had access to expert panel members, comparative data, and each other, whereas the NICU QI group had none of those elements. For the second goal, the nonparticipants did not have the change package, metrics grid, data-tracking recommendations, or the community of practice. By comparing the 2 models with nonparticipants, we were able to demonstrate the incremental effect of each QI model, while accounting for secular trends.

Patients in all 3 groups had significant reductions in hypothermia, surfactant use, and delivery room intubation and significant increases in CPAP use. The frequency of surfactant administration in the collaborative QI was higher at baseline than nonparticipants, suggesting that the collaborative QI group had more room to improve. In fact, the postintervention rate for collaborative QI remained higher than both the baseline and postintervention rates of the other 2 groups. The lower rate of surfactant use at baseline for nonparticipants may have been 1 reason that these NICUs were not as interested in joining either QI project.

A previous single-center study of improving delivery room management for preterm infants had similar goals and led to reduced hypothermia and oxygen use, but not a decrease in intubations. That study did not have a nonparticipant group for comparison. A similar single-center study found a reduction in hypothermia (defined in that study as temperature <36°) from 55% to 6%. It is difficult to compare our groups with theirs because of differing definitions and their much higher baseline rate of hypothermia. Comparing the 3 groups in our study allowed us to control for secular trends toward better delivery room temperature regulation and establishment of lung volumes during resuscitation, even without QI participation. We speculate that nonparticipant hospital improvements resulted from generic knowledge dissemination, partly due to release of the 2011 NRP guidelines. Interaction through state meetings, conferences, and other communications could have also spread to this group, a potential benefit of belonging to an informal community of practice.

We were able to identify the incremental effect of a collaborative approach compared with similar QI efforts outside of a formal collaborative environment. Specifically, although collaborative QI participation resulted in greater reductions in hypothermia and intubation, there was not a significant incremental effect in NICU QI compared with nonparticipants. There were increased
trends toward improvements in several outcomes when comparing NICU QI hospitals to nonparticipants for crude rates (Fig 1), but only surfactant use remained prominent in multivariable analyses (Fig 2). As the interventions used by both groups relied on a common toolkit, the processes related to intercenter collaboration may have led to the significantly greater degree of improvement seen for the collaborative QI group.

Of note, the collaborative QI group had an increase in hyperthermia. The 8.8% incidence of hyperthermia in the collaborative group compared with 4.1% in both NICU QI and nonparticipants represents a potentially concerning risk of temperature control elements. We did not find an association of decreased hypothermia to increased hyperthermia ($P = .47$) when categorizing the collaborative QI into terciles of performance. Careful attention to avoiding excessive warming is necessary when pursuing QI in this area. Analyses of other balancing measures (epinephrine use and chest compressions in the delivery room, and pneumothorax) were reassuring.

Reports of multicenter collaborative QI projects in adult and pediatric medicine settings have demonstrated improvements over time when comparing outcomes at the end of the collaborative with baseline.$^{32–36}$ A limitation of these studies is the lack of prospective controls. Some reports have incorporated simultaneous control groups, including cluster randomization protocols.$^{37–39}$ Although the studies by Horbar et al$^{38}$ and Scales et al$^{39}$ reported significant improvements in primary outcomes based on process implementation, the large multicenter NICHD trial by Walsh et al$^{37}$ failed to demonstrate significant differences in the primary outcome of survival without bronchopulmonary dysplasia despite wide adoption of practices. The study of collaborative multicenter practice may have some advantages to traditional randomized controlled...
trials in understanding strategies for effective QI.40

This study was subject to several limitations. We did not actively collect process metrics for the NICU QI or nonparticipant populations. However, surrogate measures of engagement were as follows. The average number of individuals on the leadership team for each NICU was 3.8 for collaborative QI and 2.7 for the NICU QI hospitals ($P = .01$), and all members of the collaborative QI group entered extranet data for 100% of the months during the intervention, whereas only 22 of the 35 NICU QI hospitals submitted electronic data forms (of those centers, forms were submitted for 92% of the months). Study groups were not selected randomly, but by voluntary enlistment on a first-come basis, introducing potential bias related to degree of commitment, interest in the topic, and general culture for QI at individual centers. Nonparticipants that did not volunteer for either group would be expected to have less intrinsic motivation. Centers with more motivation and QI organization may have better results. The collaborative QI hospitals generally had higher patient volume (Table 3), which may signify more baseline resources to perform QI, and perhaps a greater opportunity to refine practices due to more patients. We do not yet know the sustainability of the intervention beyond the 12-month postintervention period.

CONCLUSIONS

In this study, sites participating in a formal IHI style collaborative QI initiative had improved delivery room outcomes compared with both a formal single-site QI initiative, and nonparticipation. The interaction and exchange of experiences between sites within a QI collaborative project may have led to measurable gains in outcomes as compared with sites that implemented a similar change package locally without interaction with other sites. We hypothesize that building a community of practice could be 1 reason for the incremental improvement seen for collaborative QI over single-site QI. Our collaborative project also included and emphasized the use of checklists and debriefing to improve team performance and communication. This may have facilitated the ability to learn and adapt from the simultaneous experience of teams from similar organizations, leading to greater success. We also have shown the importance of tracking outcomes in nonparticipants to adjust for concurrent trends in clinical practice when reporting results of QI projects. Without the prospective data collection from this group, mistaken conclusions regarding efficacy of both QI methods may have occurred.

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