Seminars in Perinatology 46 (2022) 151629

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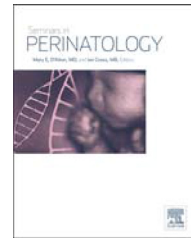

Quality improvement for neonatal resuscitation and delivery room care

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ABSTRACT

Quality improvement has become a foundation of neonatal care. Structured approaches to improvement can standardize practices, improve teamwork, engage families, and improve outcomes. The delivery room presents a unique environment for quality improvement; optimal delivery room care requires advanced preparation, adequately trained providers, and carefully coordinated team dynamics. In this article, we examine quality improvement for neonatal resuscitation. We review the published literature, focusing on reports targeting admission hypothermia, delayed cord clamping, and initial respiratory support. We discuss specific challenges related to delivery room quality improvement, including small numbers, data collection, and lack of benchmarking, and potential strategies to address them including simulation, checklists, and state and national collaboratives. We examine how quality improvement can target equity in delivery room outcomes, and explore the impact of the COVID-19 pandemic on delivery room quality of care.

Introduction

Quality improvement (QI) is a formal approach to examining performance, and a structured approach to improving it. It focuses on incorporating evidence and best practices into reliable systems of care to produce the best outcomes. Though traditional research is fundamental to advancing care, QI is necessary for that research to be appropriately and effectively applied. In neonatal intensive care, QI has the potential to markedly improve outcomes.[1,2]

The delivery room presents a unique environment for QI efforts. Although algorithms from the International Liaison Committee on Resuscitation (ILCOR) and the Neonatal Resuscitation Program (NRP) provide highly standardized care protocols, neonatal resuscitation is an intense and acute process that requires advanced preparation, rapid decision-making, and carefully orchestrated team dynamics to achieve optimal outcomes. Neonatal resuscitation is also a rare event, making standard QI approaches more challenging.

In this article, we review quality improvement for newborn delivery room care. We review the published literature, focusing on reports targeting admission hypothermia, delayed cord clamping, and initial respiratory support. Based on these reports, we offer frameworks for QI efforts in these areas through example driver diagrams. We discuss specific challenges related to delivery room improvement, and potential strategies to address them. We then examine how quality improvement can target equity in delivery room outcomes, and explore the impact of the COVID-19 pandemic on delivery room quality of care.

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https://doi.org/10.1016/j.semperi.2022.151629
0146-0005/

Delivery room quality improvement: areas of focus in the literature

Structured improvement efforts have impacted numerous aspects of neonatal resuscitation and delivery room care. Most of the published QI reports related to NRP can be grouped into three general topic areas: prevention of hypothermia, delayed cord clamping, and optimizing respiratory care. Below and in Table 1, we review a selection of recent QI efforts in each of these areas. Publications were included based on applicability to other centers through clear delineation of QI methodology, including goals, measures, interventions, and outcomes. In addition, publications were included if their improvement efforts specifically focused on the delivery room; in particular, projects targeting antenatal interventions such as use of antenatal corticosteroids or magnesium sulfate and projects addressing the first hours of life that extended beyond the delivery room to initial care in the NICU were not included.

Prevention of hypothermia

Hypothermia after birth is a common complication in low birth weight preterm births, due to heat and water loss from increased body surface area, limited insulating fat, and immature skin. Hypothermia upon admission to the NICU is associated with neonatal morbidity and mortality.[3–5] Numerous interventions have been shown to reduce heat loss and improve temperature regulation, including use of radiant warmers, early removal of wet blankets, pre-warming surfaces, use of exothermic warming mattresses, use of plastic wraps or polyethylene bags, and control of ambient environment temperature.[3,6] NRP guidelines now incorporate these interventions into standard DR care for preterm infants.[7] Standardization of temperature regulation in the delivery room has likely led to improved outcomes; VON data shows that admission hypothermia among VLBW infants has been decreasing across their network. However, VON data also shows that as of 2016, nearly 40% of VLBW infants continued to be cold upon admission, suggesting substantial opportunities for further improvement.[8]

Multiple reports describe efforts by single NICUs and collaboratives to reduce hypothermia through structured QI methods.[9–20] Outcome measures primarily examined temperature on NICU admission, with some reports also examining other morbidities. Process measures when used were largely adherence to checklists and standardized procedures, while two groups tracked DR/OR ambient temperature.[9,10,13] Balancing measures focused on hyperthermia. Interventions primarily targeted NRP elements such as delivery room temperature, use of exothermic mattress, and use of caps and occlusive wraps. Other interventions included pre-delivery team preparation, staff education, improved storage of necessary equipment near point of care, having a dedicated OR for all preterm deliveries, measuring infant's temperature during DR stabilization, and having staff designated to temperature control. Approaches to improvement and standardization included checklists, guidelines, or thermoregulatory bundles.[9,12–19] Some centers used a stepwise approach to implement these same interventions.[10,11,20] All NICUs were able to show reductions in their rates of hypothermia, while some saw minor increases in admission hyperthermia.

An example of a driver diagram targeting admission hypothermia is provided in Fig. 1**a**.

Delayed cord clamping

Delayed cord clamping (DCC), also known as timed cord clamping (TCC), is the practice of clamping the umbilical cord 30 to 60 s or later after birth. DCC has been shown to be beneficial in preterm and term infants. In preterm infants, DCC is associated with improved hemodynamic stability, decreased intraventricular hemorrhage, and decreased necrotizing entercolitis.[21,22] In term infants, DCC results in higher hemoglobin levels and greater iron stores, which may improve neurodevelopmental outcomes.[23] Delaying cord clamping until at least 30 to 60 s after birth is now recommended in NRP guidelines for all vigorous infants, as well as by ACOG/AAP for all vigorous infants.[7,23,24] However, implementation of this evidence based practice has not yet been universal; a review of 52 NICUs in California in 2016 found rates of DCC ranging from 0 to 74.5%.[25]

Multiple centers have used QI methods to successfully implement or improve DCC practices.[26–32] Outcome and process measures included rates of DCC, morbidities such as IVH and NEC, and need for transfusions. Most efforts incorporated multidisciplinary teams involving nursing, obstetrics, and neonatology, and interventions tended to focus on VLBW infants. Improvement approaches included educational sessions and development of standard guidelines and protocols.[26–31] All of the reports showed significant improvements in DCC rates, although sustaining high rates was inconsistent. One center reported compliance rates between 18% and 93%, depending on the month, though they were able to show an overall trend of improvement.[27] Another team that was particularly successful with rates of delayed cord clamping up to 85% had an immediate post-delivery review with an NNP/neonatologist discussing why or why not delayed cord clamping was done during a particular delivery.[31] Importantly, many units were also able to show improvement in clinically outcomes, most commonly an increase in hematocrit with a decrease in transfusion need in VLBW infants, with some also demonstrating decreased IVH, decreased delivery room intubation, and decreased RDS. [26,28,29,32]

Balancing measures typically included admission hypothermia, jaundice requiring phototherapy,[26] and polycythemia.[29] Some reports evaluated multiple measures including Apgar scores, need for resuscitation, and clinical outcomes without specifying whether these were considered process, outcome, or balancing measures.[28,29]

Concerns about delaying resuscitation in VLBW infants, as well as concern for maternal hemorrhage have been cited as reasons teams have struggled with compliance with DCC.[33] Reassuringly delayed cord clamping has not been shown to adversely affect either maternal or neonatal outcomes.[34]

An example of a driver diagram targeting delayed cord clamping is provided in Fig. 1**b**.

Table 1 – Selected publications describing quality improvement in neonatal resuscitation.

Publication	Population	Selected Process Measures and Outcomes	Selected Balancing Measures	Selected Interventions and Approaches to Improvement
ADMISSION TEMPERATURE				
Billimoria[11] 2013	BW 1000 grams	Rates of hypothermia on admission (core T < 36°C) Usage of plastic wrap and rates of reopening wrap during DR care	Rates of hyperthermia on admission (core T > 37.5°C)	Standardized delivery room temperature Use of chemical warming mattress and plastic bags Staff education on available equipment and assignment roles in DR Pre-warmed transport isolette and chemical warming mattress during transport to NICU
Manani[17] 2013	GA < 33 weeks and BW < 1500 grams	Rates of hypothermia on admission (core T < 36°C) Survival without serious morbidity Adherence to pre-delivery preparation plan	Rates of hyperthermia on admission (core T > 37.5°C)	Staff education Pre-delivery preparation (warmer heat output, ambient temperature, warming mattress, polyethylene wrap) Standardized DR management Designated temperature management nurse in DR
DeMauro[12] 2013	BW 1250 grams	Rates of normothermia on admission (core T 36.5°C - 37.5°C) Checklist completion Use of thermoregulation equipment	Rates of hyperthermia on admission (core T > 37.5°C)	Pre-delivery and post-delivery checklist Heat loss prevention guidelines
Pinheiro[16] 2014	GA 28 weeks	Rates of hypothermia on admission (core T < 36°C) Thermal environment data	Rates of hyperthermia on admission (core T > 38°C) Low Apgar scores Chest compressions +/- epinephrine use Mortality	Thermoregulatory bundle Battery powered warmer
Russo[9] 2014	GA < 35 weeks	Rates of hypothermia on admission (core T < 36°C) Weekly OR and DR temperature reports	Rates of hyperthermia on admission (core T > 37.5°C)	Occlusive wrap without drying infant Warming mattress Double hats Radiant warmer to 100% Delivery room temperature set to 71-74°F
Harer[13] 2017	GA < 35 weeks	Median admission temperature Appropriate delivery room temperature	Rates of hyperthermia on admission (core T > 37.5°C)	Gestational age-specific algorithm Consistent measurement of infant temperature Uniform transport of newborns
Andrews[18] 2018	GA 35 weeks and directly admitted to mother-infant unit	Rates of hypothermia in first 24 hours (core T < 36°C) Variations in mother-infant room temperature	Rates of hyperthermia in first 24 hours (core T > 37.5°C)	Drying of infant before skin-to-skin Use of hats Delayed first bath Provider assessments performed under radiant warmer
Vinci[14] 2018	GA < 32 weeks	Rates of hypothermia on admission (core T < 97° F) Adherence to checklists	Rates of hyperthermia on admission (core T > 100.4°F)	Creation of 10 item delivery room checklist Increased delivery room temperature
Bhatt[15] 2020	BW < 1000 grams	Rates of normothermia on admission (core T 36.5°C - 37.5°C)	Rates of hyperthermia on admission (core T > 37.5°C)	Thermoregulation bundle (17 elements)

Table 1 (*continued*)

Publication	Population	Selected Process Measures and Outcomes	Selected Balancing Measures	Selected Interventions and Approaches to Improvement
Sharma[20] 2020	BW 500-1499 grams and GA 25 weeks	Mean admission temperature Death before discharge Major morbidities (severe IVH/PVL, severe ROP, NEC)	None described	Delivery room temperature set to > 23°C Standardized delivery room preparation Use of heat cap, warm towels, heated transport system
Schwarzmann[10] 2020	All inborn infants directly admitted to the NICU	Incidence of hypothermia on admission (core T < 36°C)	Rates of hyperthermia on admission (core T > 38°C)	Standardized delivery room temperature In-service education for all staff in delivery rooms (Obstetricians, Neonatologists, RNs, RTs, etc.) Standardized exothermic mattress and occlusive wrap use
Sprecher[19] 2021	All inborn infants with NICU team present at delivery	Incidence of hypothermia on admission (axillary T < 36.5°C) Delivery room ambient temperature Staff knowledge of hypothermia prevention guidelines	Rates of hyperthermia on admission (core T > 38°C)	Standardized delivery room temperature Increased use of heat mattresses and polyethylene bags Staff education through in-person education, guideline cards, placard reminders on radiant warmers in DR
DELAYED CORD CLAMPING				
Aziz[27] 2012	GA < 33 weeks	Compliance with DCC protocol	Peak bilirubin level Apgar scores Rates of admission hypothermia	DCC algorithm Staff education
Chiruvolu[32] 2015	GA 32 weeks	Incidence of IVH Needs for pRBC transfusion	Apgar scores Admission temperature	Implementation of protocol-driven DCC
Ruangkit[29] 2015	GA < 34 weeks	Compliance with DCC protocol Success rate of DCC	Incidence of polycythemia Apgar scores Rates of admission hypothermia Peak bilirubin level	Protocol checklist and procedural guidelines for DCC
Bolstridge[26] 2016	GA < 37 weeks	Adherence to DCC protocol Need for pRBC transfusion or respiratory support Rates of NEC, IVH, PVL, late onset sepsis	Use of phototherapy Incidence of hypothermia (core T < 36°C)	New protocol for delayed cord clamping
Liu[28] 2017	GA < 32 weeks	Adherence to DCC protocol	Peak bilirubin level	Implementation of DCC protocol Staff education and re-education
Aliyev[30] 2018	GA < 37 weeks	Rates of DCC Apgar scores DCC Survey results	None described	Implementation of DCC protocol
Pantoja[31] 2018	GA < 35 weeks	Rates of DCC	None described	DCC clinical practice guideline Staff education DCC as a quality indicator
RESPIRATORY CARE				
DeMauro[12] 2013	BW 1250 grams	Amount of supplemental oxygen administered in the DR Compliance with FiO_2 titration guidelines Intubation rates without a trial of CPAP	Rates of pneumothorax Need for cardiopulmonary resuscitation in the DR	FiO2 titration guidelines Non-invasive respiratory support as first line respiratory management in all deliveries Specific intubation and surfactant usage criteria
Templin[38] 2017	GA 24 - 27 weeks	Rates of mechanical ventilation in first 3 days of life	LISA complications Severe morbidity or mortality	New nCPAP device Higher PEEP in DR Implementation of a LISA protocol

Table 1 (*continued*)

Publication	Population	Selected Process Measures and Outcomes	Selected Balancing Measures	Selected Interventions and Approaches to Improvement
Berneau[39] 2018	GA < 30 weeks	Survival without moderate to severe BPD at 36 weeks PMA Days of mechanical ventilation Duration of first ventilation period	Physiologic tolerance to LISA procedure Rates of pneumothorax Apnea ± bradycardia during intervention Unbalanced surfactant administration Surfactant reflux	Implementation of a LISA protocol
Kubicka[37] 2018	BW < 1500 grams	Rate of CLD ± death Need for home supplemental oxygen Medical/surgical therapy for echocardiography-proven PDA Length of stay	Severe IVH Severe ROP NEC (Bell stage 2 or higher) Rates of pneumothorax	CPAP/NIPPV as primary respiratory support in DR
Kakkilaya[40] 2019	GA 29 weeks	Rate of delivery room intubation	Duration of bradycardia Time to NICU admission Rates of hypoglycemia (<40 mg/dL) Incidence of hypothermia (T < 36°C) Rates of pneumothorax	Standardized PPV pressures Increasing inspiratory time prior to intubation attempt Simulation training with MRSOPA Use of round face masks for PPV Documentation of MRSOPA steps and indication for intubation
Lo[42] 2021	GA < 32 weeks	Exposure to mechanical ventilation in DR, during first 72 hours, during entire NICU admission Duration of mechanical ventilation Incidence of BPD Combined BPD/death rates	Death prior to discharge Combined BPD or death incidence PDA rates NEC, ROP, severe IVH, PVL	DCC after establishment of spontaneous breathing Optimizing CPAP as initial mode of respiratory support in DR MIST method for surfactant for infants on CPAP
Jardine[41] 2021	GA < 32 weeks	Intubation rates in the DR	Intubation rates at < 4hr of age, < 24hr of age, <72hr of age	Use of appropriate equipment and optimal set up in DR Implement usage of bubble CPAP in DR Education and staff training prior to implementation

Abbreviations: BPD, bronchopulmonary dysplasia; BW, birth weight; CLD, chronic lung disease; CPAP, continuous positive airway pressure; DCC, delayed cord clamping; DR, delivery room; GA, gestational age; IVH, intraventricular hemorrhage; LISA, less invasive surfactant administration; MRSOP, modified NRP MRSOPA: mask adjustment, reposition airway, suction, open mouth, pressure increase; nCPAP, nasal continuous positive airway presses; NEC; necrotizing enterocolitis; NIPPV, non-invasive positive pressure ventilation; OR, operating room; pCO2, partial pressure of carbon dioxide; PDA, patent ductus arteriosus; PEEP, positive end expiratory pressure; PMA, postmenstrual age; PPV, positive pressure ventilation; pRBC, packed red blood cells; PVL, periventricular leukomalacia; QI, quality improvement; ROP, retinopathy of prematurity; T, temperature; WBN, well baby nursery

Improving respiratory care

Respiratory care in the delivery room is multifactorial. The transition from intrauterine to extrauterine life includes an enormous shift, as the lungs fill with air, and pulmonary vascular resistance drops. Oxygen saturation rise dramatically over the first 10 min of life, starting at 60–65% at 1 min of life, and reaching 85–95% by 10 min.

Supporting this transition with respiratory interventions may be the most critical component of NRP. Recently, growing evidence has shown that delivery room respiratory care can impact outcomes beyond immediate resuscitation, including improving long-term outcomes such as bronchopulmonary dysplasia (BPD) in preterm infants through increased use of non-invasive support with CPAP.[35] Current NRP guidelines recommend initial respiratory support of spontaneously breathing preterm infants with labored respirations or needing oxygen with CPAP.[7] VON data shows that the use of CPAP in the delivery room has steadily increased across the network.[36] However, it is not known how often CPAP is not used when it might be appropriate.

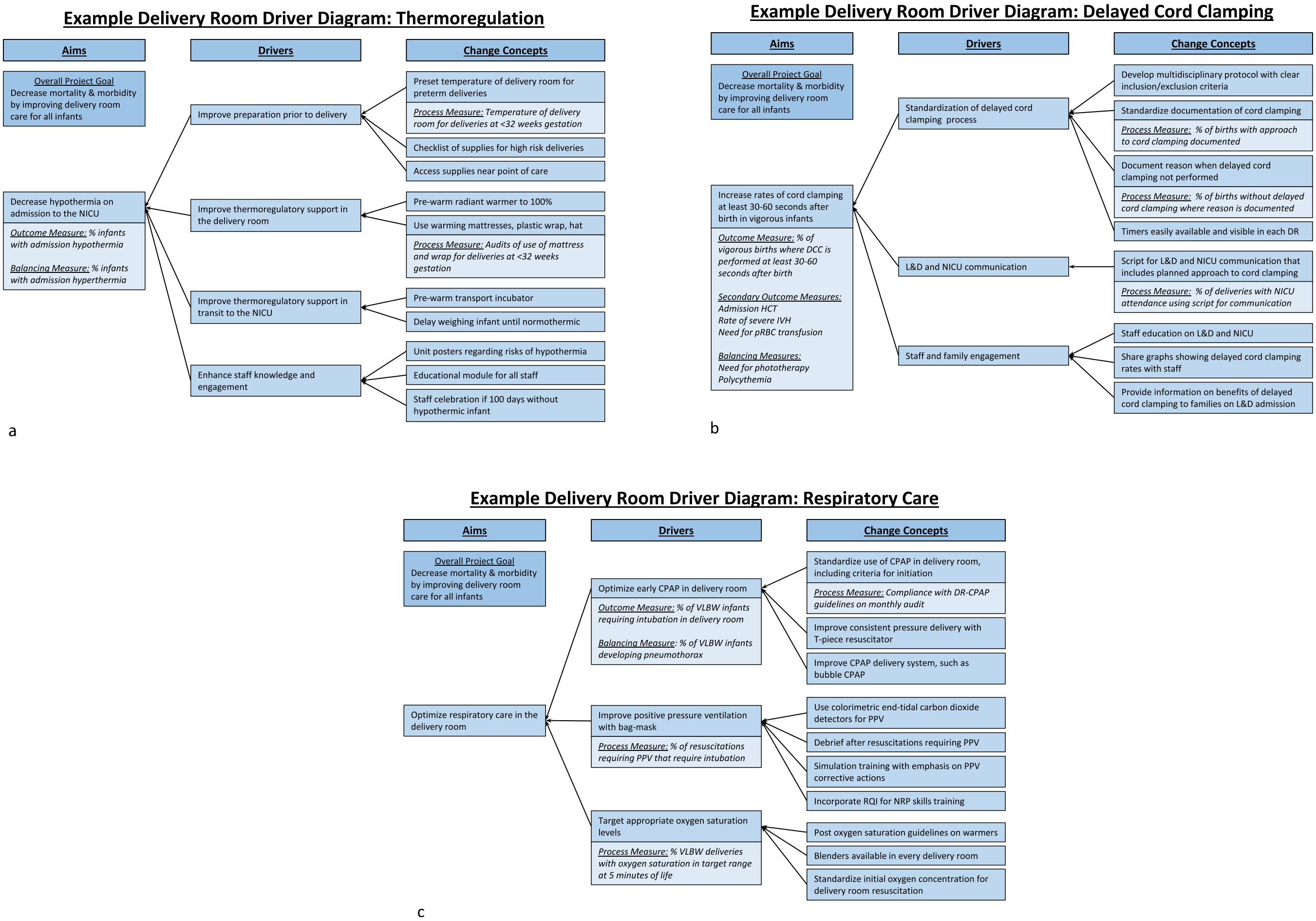

Fig. 1 – Example driver diagrams for delivery room quality improvement initiatives: Fig. 1a: Thermoregulation; Fig. 1b: Delayed cord clamping; Fig. 1c: Respiratory care. Note: Driver diagrams are meant to be examples of quality improvement frameworks; actual aims, drivers, change concepts, and measures for a quality improvement effort should be determined by local context and the local improvement team.

Several QI reports have targeted optimizing respiratory support in the delivery room for preterm infants, with a goal of reducing intubation and mechanical ventilation.[12,37–42] Areas of focus included improved use of CPAP or NIPPV, specific use of bubble CPAP, use of less-invasive surfactant administration, and optimizing resuscitation and PPV. Outcome and process measures included delivery room intubation, measures of mechanical ventilation, and rates of BPD. Balancing measures included procedural complications, pneumothorax, and other morbidities. All the reports showed improvements in short term outcomes such as decreased intubations and decreased mechanical ventilation days, while one report showed significant reductions in BPD.[40]

Another area of respiratory focus in delivery room QI has been optimizing use of oxygen.[12,43] As the understanding of oxygen toxicity has grown, NRP has clarified and standardized appropriate saturation goals for the first minutes of life, with the goal to reduce oxygen exposure during resuscitation and yet provide adequate oxygen supplementation.[7] Low oxygen resuscitation strategy has been associated with improved neurodevelopmental outcome, decreased BPD, with no impact on mortality.[44,45] QI reports focusing on reducing initial oxygen concentration used for resuscitation, with interventions including education, guideline creation, and the use of a dedicated nurse in the delivery room, have led to sustained reduction in oxygen exposure without negative impacts on other clinical outcomes.[12,43]

An example of a driver diagram targeting delivery room respiratory care is provided in Fig. 1c.

Delivery room quality improvement: framework from the NRP

In the 8th edition of the Textbook of Neonatal Resuscitation, the NRP program provides suggestions for incorporating QI into delivery room care.[7] Each lesson is accompanied by specific questions that can help identify gaps in care and opportunities for improvement, and by process and outcome measures that could be used to guide QI efforts. A selection of these suggested measures is shown in Table 2. Supplemental lesson 14 provides an overview of QI methods, including identifying the problem, forming a team, developing a specific aim, defining measures, analyzing data over time, and

Table 2 – Potential quality improvement measures by lesson from NRP 8th edition.

Lesson	Possible Quality Improvement Measures*
2: Anticipating and Preparing for Resuscitation	Percentage of newborn providers that have completed NRP training Percentage of births that have a qualified provider present who is only responsible for newborn Percentage of births that have a standardized supplies and equipment checklist completed
3: Initial Steps of Newborn Care	Percentage of vigorous newborns with cord clamping delayed at least 30 to 60 s Percentage of newborns with meconium-stained fluid that undergo laryngoscopy and tracheal suction
4: Positive-Pressure Ventilation	Percentage of newborns that receive PPV in the delivery room Percentage of resuscitations with PPV in which a second trained provider was present at time of birth
5: Endotracheal Intubation	Percentage of newborns that are intubated in the delivery room Percentage of delivery room newborn intubations that were successful on the first attempt Rate of adverse events per delivery room newborn intubation
6: Chest Compressions	Percentage of newborns that receive chest compressions in the delivery room Percentage of resuscitations with chest compressions in which an endotracheal tube or laryngeal mask was inserted before chest compressions were started Percentage of resuscitations with chest compressions in which FiO2 was increased to 100% when compressions were started
7: Medications	Percentage of newborns that receive epinephrine in the delivery room Percentage of resuscitation team members that have demonstrated they can calculate and prepare emergency epinephrine in a simulation setting in the past year
8: Resuscitation and Stabilization of Babies Born Preterm	Percentage of preterm infants that are hypothermic (temperature < 36.5 °C) at 1 h of age Percentage of preterm infants whose parents have an opportunity to see and touch their infant within 60 min of birth Among preterm births, average time after birth at which mothers are instructed how to express or pump breast milk
9: Post-Resuscitation Care	Percentage of resuscitations in which a resuscitation record was completed Percentage of resuscitations in which team completes a post-resuscitation debriefing
10: Special Considerations	Percentage of newborns diagnosed with a pneumothorax
11: Ethics and Care at the End of Life	Percentage of extremely preterm births in which parents met with a neonatal care provider for consultation before birth Percentage of neonatal deaths in which organ procurement agency was contacted before death Percentage of neonatal deaths with documentation that parents were asked about autopsy

* Adapted from Textbook of Neonatal Resuscitation, 8th Edition, American Academy of Pediatrics, 2021.

testing changes using a plan-do-check-act cycle. Lesson 14 also offers several delivery room QI opportunities that would likely be potential targets for many units; these are summarized in Table 3.

Unique challenges of quality improvement in the delivery room

Numerous aspects of delivery room care create unique challenges for development of NRP protocols, including the unpredictability of the delivery room, urgent resuscitative needs, team complexity, and a challenging physical environment. There are also aspects of NRP that make QI efforts particularly challenging. These include: (1) small numbers, as even large centers will have infrequent code events, and only care for small numbers of ELBW infants; (2) difficult data collection, with data recorded during resuscitative events often being incomplete or inaccurate; and (3) a lack of data for benchmarking, with few standardly used quality measures for delivery room care.

Small numbers and infrequent occurrence

Conditions requiring newborn resuscitation vary widely and are infrequent, such that individual teams or hospital will experience small numbers of any given event or condition. Code events in term infants are rare, with only 0.1% of term infants receiving chest compressions and 0.05% receiving both compressions and epinephrine.[46] VLBW infants typically require carefully coordinated delivery room care and are more likely to require resuscitation, but VLBW births are also infrequent, representing only 1.4% of all births.[47] Infants with congenital anomalies often require specialized delivery room attention and can be at higher risk for needing resuscitation, but the range of congenital anomalies is extremely broad and

Table 3 – Potential delivery room quality improvement opportunities from NRP 8th edition.

Potential Quality Improvement Opportunities in the Delivery Room*
Appropriate team composition for delivery room resuscitation
Delaying cord clamping for at least 30 to 60 s
Optimizing positive pressure ventilation prior to use of alternative airway
Improving continuous positive airway pressure use and positive-pressure ventilation to reduce need for intubation
Achieving target oxygen saturations at 5 min of age for pterm newborns
Insuring 100% oxygen is being used when chest compressions are needed

* Adapted from Textbook of Neonatal Resuscitation, 8th Edition, American Academy of Pediatrics, 2021.

the incidence of each condition is extremely low. With rare events, it can be difficult to apply rigorous QI methods, including using rapid PDSA cycles to test and implement changes and measuring progress over time.

Simulation, as described elsewhere in this issue, is a key component of NRP training, offering powerful tools to address educational issues related to infrequent events and rare conditions. Skill acquisition has been shown to increase when simulation is combined with standard practice, compared to standard practice alone.[48] Traditional simulation platforms are expanding to new technologies, including virtual reality.[49] For training, simulation offers opportunities for practice as well as the ability to measure competency. These features can be easily applied to QI, where simulation can offer a platform for rapid testing of changes and measuring outcomes. As an example, simulation could be used for a QI initiative to improve timing of delivery room interventions to align with NRP standards, a standard that is known to be difficult to achieve.[49] PDSA cycles could include audio/visual prompts, checklists based on time since birth, and code cart reorganization to better reflect the sequence of events in NRP. Several tests of change could be done within simulated code events, using times measured during the simulations as outcome measures. Changes shown to be impactful in the simulations using QI methods could then be adopted into clinical care. QI programs anchored on serial on-site neonatal resuscitation simulation trainings led to increased staff participation, improved staff confidence, and perhaps most importantly, the identification of local context-specific latent safety threats.[50,51] For example, if a specific piece of equipment is not appropriately ready during repeated simulations, interventions to make the equipment easier to find and prepare will likely prevent adverse events in actual clinical care.

Beyond simulation, specific QI strategies can potentially help address the challenge of rare events in resuscitation. For initiatives targeting rare outcomes, outcome measures may have limited utility to guide improvement. When outcome measures are limited, process measures can often be valuable improvement targets, if the process measures are robustly linked to the outcome.[52] For example, many QI efforts addressing BPD focus on process measures related to respiratory care rather than BPD rates. For delivery room QI, rather than target measures addressing rare events such as code performance or resuscitation outcomes, teams could target process measures addressing more frequent occurrences, such as team debriefs, delivery room preparation, or checklist use.

Specific statistical approaches can also be used for rare events. Statistical process control (SPC) charts are widely used for time-series data analysis in QI, but commonly used SPC charts such as the P-chart, U-chart, and Xbar-S chart may have limited ability to assess variation for measures with small numerators; less commonly used SPC charts such as the T-chart and G-chart were specifically designed for rare events and may have more power for guiding improvement targeting uncommon outcomes.[53,54]

Data collection

Measurement is foundational to quality improvement. Many clinical outcome and process measures rely on data abstracted from documentation in medical records. In the delivery room, this can be uniquely challenging. Documentation of delivery room resuscitation is known to be inaccurate, particularly around resuscitative events and interventions.[55] Personnel present at the delivery are limited, as is space for the recorder who may struggle to hear and record timing of events. Recall of events for retrospective documentation may be difficult due to the acuity and urgency of resuscitations.

Several strategies can be used to improve data recording and acquisition in the delivery room. Checklists have been shown to be effective tools for standardizing care practices. The California perinatal quality collaborative incorporated checklists into a readiness bundle for delivery room teamwork and communication, and used QI methods to successfully implement the checklists and bundle across 24 NICUs.[56] In addition to their use as a tool to guide care, however, checklists also offer the opportunity to concurrently measure performance.[57] Well-designed checklists can simplify documentation, and make accurate documentation at the point of care simpler and more reliable.

Video recording can also aid with data collection for NRP QI. A tool that is most commonly used for simulation debriefing and research, video capture of live neonatal resuscitation can function as an objective, retrospective source for data collection that can improve adherence to guidelines when used.[58] Recording of all resuscitations has become standard at some centers. This is a resource-intensive endeavor, however, and not all centers will have personnel or technology resources required. Other potential constraints around video recording include the need for family consent and considerations around patient and staff privacy.

Lack of benchmarking

Benchmarking compares performance with an external standard. It is a core element of quality assurance and can provide important context for quality improvement. For example, a NICU that increases their rates of timed cord clamping from 20% to 60% may feel appropriately satisfied with their achievements, but benchmarking data showing cord clamping rates at other centers may indicate that there is still substantial opportunity for further improvement. Benchmarking has been widely used in neonatal intensive care, driven largely by networks such as the Vermont Oxford Network (VON), a large international NICU QI collaborative. By combining benchmarking with multi-site collaboration, VON has proven to be widely effective at improving outcomes.[59]

While NICUs routinely benchmark performance using VON and other networks for key measures such as mortality, infection, and BPD, benchmarking using delivery room measures is less common. One VON measure related to delivery room care that has been widely used is admission temperature. Initial VON data showed that over half of all very low birth weight infants in the network were hypothermic on admission; this supported QI efforts by individual units and larger networks that led to significant improvement in temperature regulation for VLBW infants across the country.[8] The VON database also includes multiple other delivery room measures such as Apgar scores and elements of resuscitation; to date, these have been less commonly used for benchmarking.

More recently, state-based perinatal quality collaboratives (PQCs) have provided additional opportunities for benchmarking among neonatal units in a state or region. State PQCs have proven effective drivers of collaborative quality improvement; as compared to national organizations, they are able to address more targeted improvement aims, incorporate more granular data collection, and utilize local expertise and networking. PQCs generally structure collaborative QI projects around data collection that includes comparison of performance among participating units, and use of that benchmarking to drive improvement. Several PQCs have reported efforts focused on the delivery room and neonatal resuscitation; selected examples are summarized in Table 4. The California Perinatal Quality Care Collaborative (CPQCC)

Table 4 – Selected publications from state perinatal quality collaboratives describing quality improvement in neonatal resuscitation

Publication	Population	Selected Process Measures and Outcomes	Selected Balancing Measures	Selected Interventions and Approaches to Improvement
Lee[61] 2014 (CPQCC)	GA < 30 weeks or BW < 1500 grams	Rates of hypothermia (T < 36.5°C) Frequency of CPAP, intubation and surfactant in DR	Rates of hyperthermia (T > 37.5°C) Use of chest compressions or epinephrine in DR Pneumothorax rates	Thermoregulatory bundle Pulse oximetry within 2 minutes of life Emphasize CPAP over intubation and surfactant use Checklists, briefings and debriefings
Bennett[56] 2016 (CPQCC)	All infants requiring resuscitation and admitted to the NICU	Successful integration of a Readiness Bundle Compliance with briefings, debriefings and checklists Survey results of QI participants in 6 month intervals	None described	Briefing prior to all deliveries Implementation of a delivery room checklist Debriefing after all deliveries
Balakrishnan[64] 2017 (FPQC)	GA < 32 weeks or BW < 1500 grams	Time to NICU admission Rates of DCC Hematocrit NICU admission temperature Pre-ductal oxygen saturation at 10 minutes of life	5 minute Apgar score Rates of hyperthermia (T >37.5°C) Use of chest compressions or epinephrine in DR	Standardized equipment, policies, procedures for deliveries Pre-defined resuscitation team roles Simulation-based team training Equipment checklists Team debriefing
Talati[63] 2019 (TIPQC)	All infants requiring resuscitation	Survival to discharge Rates of IVH, severe ROP, BPD Usage of resuscitation checklists Documentation of family updates, briefings and debriefings Saturations within NRP target range Time to IV access, IV glucose administration, IV antibiotics	Admission temperature Initial pCO_2	Pre-resuscitation checklists Team briefing and debriefing Family updates within 1 hour of delivery Oxygen titration per NRP saturation targets Decreased time to IV access, IV glucose administration, IV antibiotics

Abbreviations: CPQCC, California Perinatal Quality Care Collaborative; FPQC, Florida Perinatal Quality Collaborative; TIPQC, Tennessee Initiative for Perinatal Quality Care supported 20 hospitals in a delivery room management initiative that successfully decreased admission hypothermia, delivery room intubation and surfactant administration, with these improvements associated with lower rates of BPD.[60,61] The Tennessee Initiative for Perinatal Quality Care (TIPQC) brought together nine NICUs in a neonatal resuscitation improvement effort, and showed significant improvement in processes such as use of checklists and team briefings and in outcomes such as time needed to accomplish steps in resuscitation.[62] Importantly, their collaborative allowed for collection of delivery room quality measures not typically collected, such as time to intravenous access, time to initiation of glucose infusion, and time to antibiotic dosing. The Florida Perinatal Quality Collaborative (FPQC) included nine hospitals in a delivery room project that led to improvements in pre-delivery preparedness, delayed cord clamping, admission temperature, and post-delivery debriefing.[63]

While these examples from VON and state PQCs are valuable demonstrations of the use of delivery room quality measures, overall, opportunities for widespread benchmarking of neonatal resuscitation performance remain limited other than for admission temperature. For neonatology as a field, developing additional rigorous quality measures specific to delivery room care that can be used broadly should be an ongoing area of focus. In the meantime, regional and state collaboratives may provide opportunities for units to benchmark performance on specific aspects of care within a more targeted community.

Targeting equity in the delivery room

Inequities in care and outcomes persist in all areas of medicine, including the NICU. Significant racial and ethnic variations in quality of care have been described within NICUs as well as between NICUs.[64,65] When evaluating outcomes of ELBW infants in NICUs participating in VON from 2006 to 2017, there was a decline in racial and ethnic disparities around certain outcomes; however, differences in outcomes persisted, particularly around hypothermia, mortality, necrotizing enterocolitis, late-onset sepsis, and severe intraventricular hemorrhage.[66] Many of these outcomes are modifiable, highlighting the role for targeted quality improvement initiatives. With regards to newborn resuscitation, disparities specific to delivery room outcomes such as admission hypothermia have been described.[67]

Communication can further drive inequities. Families with limited English proficiency (LEP) are at particular risk for communication challenges, especially if interpreter services are not readily available.[68] In obstetrics, there is evidence that limited English proficiency contributes to maternal complications as well as higher rates of primary cesarean delivery.[69] In the NICU, infants of families that require interpreters have been shown to have a longer length of hospitalization than families that are English proficient,[70] and that families with LEP are overall less prepared for discharge.[71]

To date, delivery room QI publications have largely not investigated potential inequities nor developed interventions specifically targeting equity. Increasingly, however, methods are being developed to enable teams to incorporate equity into their QI efforts. Reichman et al. recently shared a framework for Equity-Focused Quality Improvement (EF-QI), defining EF-QI as "initiatives that integrate equity throughout the fabric of the project and are inclusive, collaborative efforts that prioritize and address the needs of disadvantaged populations".[72] Highlights of their framework include: (1) creating a culture of equity where a discussion around equity is incorporated into every project; (2) identifying disparities by stratifying quality measures by race, ethnicity, language and other sociodemographic variables; (3) focusing on root causes and developing interventions specifically targeting improvement for disadvantaged populations; and (4) involving a diverse set of families in the design of each project with a true co-design model.

Some aspects of this framework may be challenging for single center delivery room QI efforts, particularly around stratification of data for rare outcomes, but most aspects can and should be incorporated into all improvement activities, whether local or collaborative. As a field, greater study of the potential impact of systemic racism on delivery room care and outcomes should be a priority.

Influence of COVID-19

The COVID-19 global pandemic has placed a new challenge on delivery room care. Obstetrical and newborn services had to adapt to rapidly changing guidance around infection prevention and control while maintaining a high level of patient care. To accomplish this task, there has been a requisite balance of providing appropriate protection for healthcare workers while meeting the needs of the parent and neonate.[73] NRP has always provided clear guidelines surrounding resuscitation including equipment and team composition, recognizing that there may be small differences based on location and staffing. However, the unprecedented changes required during this pandemic have altered routine practice, and these changes have the potential to compromise care. Examples of potential negative impacts in the delivery room include: delays in reaching a resuscitation due to need for the resuscitation team to don personal protective equipment; changes in location of resuscitation or team composition impacting delivery room protocols or team function; and less effective positive pressure ventilation due to use of viral filters.[74] Beyond the delivery room, changes in visitor policies, skin-to-skin care, rooming in, and breastfeeding have likely had substantial impacts on initial newborn care.[75] To date, little has been written about the impact of the pandemic on delivery room outcomes, or quality improvement initiatives that have targeted delivery room care in the era of COVID-19.

With these challenges, however, have come opportunities. The pandemic has also created new methods of providing education and simulation experience for NRP learners. NRP developed an interim strategy for instructors to use during the pandemic, which has been utilized at centers to continue providing necessary education.[76] Individual programs have been following this guidance with success, and have shown that overall learner satisfaction is unchanged in a "Socially Distanced NRP" model when compared to standard NRP education.[77] This model works well when combined with previously mentioned innovations such as video-assisted laryngoscopy, allowing for safe teaching of intubation technique from a socially-distanced space. Tele-simulation and remote learning are methods that can be utilized well after the pandemic, and could serve to expand NRP education and QI efforts to more centers; these virtual collaborations could be designed to specifically address some of the specific QI challenges described above, such as small numbers and lack of benchmarking.

Conclusions

Quality improvement has had significant impact on delivery room care and outcomes. While most published reports have focused on admission temperature, delayed cord clamping, or respiratory support, virtually all areas of neonatal resuscitation would be amenable to structured approaches to improvement. Challenges specific to delivery room QI are substantial, but can be addressed through creative approaches including simulation, technology, checklists, and collaborations. QI efforts in this area will continue and grow, and we will develop better approaches to important improvement areas such as developing standardized measures, benchmarking and targeting equity. As we do, all centers that care for newborns in the delivery room should strive to incorporate quality measurement and improvement strategies in their neonatal resuscitation program.

Disclosures

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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