Implementation of an Extubation Readiness Guideline for Preterm Infants

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ABSTRACT

Background: Intubated preterm infants $32^6/_7$ weeks or less of gestation in a mid-Atlantic level IV neonatal intensive care unit (NICU) faced a high number of ventilator days. Based on 6 weeks of electronic health record (EHR) chart audits of extubations in this NICU in 2021, 44% of preterm infants $32^6/_7$ weeks or less of gestation were intubated for more than 28 days, with an average of 23 days on a ventilator. This NICU lacked a standardized extubation guideline providing criteria to drive extubation eligibility.

Purpose: The purpose of this quality improvement (QI) project was to implement and evaluate the effectiveness of an extubation readiness guideline in preterm infants $32^6/_7$ weeks or less of gestation in a mid-Atlantic level IV NICU.

Methods: This project occurred over a 17-week period in 2021. Implementation included a multidisciplinary committee formation, identification of champions, NICU staff education, completion of a guideline checklist by bedside nursing (for eligible patients), clinician reminders, and chart audits for collection of pre-/postimplementation data. Staff education completion, guideline use and compliance, demographic patient data, ventilator days, time to first extubation, and need for reintubation were tracked.

Results: Postimplementation data indicated decreased need for intubation for more than 28 days, ventilator days, and days to first extubation attempt.

Implications for Practice and Research: Results suggested that implementation of the evidence-based guideline was effective in decreasing average total ventilator days for preterm infants $32^6/_7$ weeks or less of gestation.

Key Words: airway, extubation, preterm, infants, ventilator, weaning, guideline

Respiratory distress syndrome (RDS) is a breathing disorder affecting nearly 100% of infants born before 28 weeks of gestation.[1] RDS symptoms typically develop in the first 24 hours after birth, are a result of inadequate surfactant production, and may require an infant to need mechanical ventilation.[1] Preterm infants subjected to long periods of mechanical ventilation often face complications as a result of a high number of ventilator days. Bronchopulmonary dysplasia (BPD) is a complication seen with longer duration of mechanical ventilation.[2] Preterm infants continuing to require supplemental oxygen 36 weeks of corrected gestational age are diagnosed with BPD.[1] Approximately 10,000 to 15,000 infants are diagnosed with BPD each year, in the United States.[2] Infants with BPD are at risk for delayed growth in the first 2 years of life, need for ongoing oxygen therapy and respiratory treatments, increased risk for infection, increased risk for asthma, and trouble swallowing.[2]

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Ethical approval was provided by the Institutional Review Board of both the University and Hospital in advance of implementation. Written informed consent was not deemed necessary per Institutional Review Board of both the University and Hospital.

The authors declare no conflicts of interest.

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PREIMPLEMENTATION DATA

Intubated preterm infants $32^6/_7$ weeks or less of gestation in a mid-Atlantic level IV neonatal intensive care unit (NICU) faced a significantly high number of days on the ventilator. On average, over 700 patients are admitted to this NICU annually, with roughly 1 newly admitted intubated preterm infant $32^6/_7$ weeks or less of gestation per week. Generally, over 50% of infants less than 32 weeks of gestational age and over 75% of infants less than 29 weeks of gestational age require some form of breathing assistance during their stay in this NICU. In 2020, preterm infants $32^6/_7$ weeks or less of gestation in this NICU averaged 143 ventilator days per month. In 2020, this NICU had 22.0% of very low-birth-weight (VLBW, <1000 g) infants on a ventilator for more than 28 days, compared with a median of 15.7% infants in other similar NICUs throughout the United States.[3] In regard to BPD, this NICU had a 53.3% incidence of BPD in infants less than 33 weeks of gestational age and of VLBW versus a 30.9% median incidence of BPD in other similar NICUs throughout the United States.[3]

LITERATURE REVIEW

A literature review focused on methods utilized to support successful extubation of the preterm infant was performed (Table 1, and Supplemental Appendix 1, available at: http://links.lww.com/ANC/A244). A systematic review with meta-analysis for successful extubation, multiple mechanical ventilation cohort studies, extubation bundles, extubation protocols, and extubation guidelines, all specific to neonatal patients and/or preterm infants were analyzed. Literature involving exclusively full-term infants was not explored.

Specifically, in a systematic review with meta-analysis, of 47 studies in a qualitative synthesis and 34 studies in a meta-analysis, Ferguson et al[4] found that for preterm infants less than 37 weeks of gestation, noninvasive respiratory support is beneficial postextubation and methylxanthines reduce extubation failure. In a quality improvement (QI) initiative, Eissa et al[6] found that the use of an extubation bundle with specific components, for preterm infants 30 weeks or less of gestation, could result in successful extubation. With use of an extubation protocol, Mandhari et al[7] found that a 2-stage extubation readiness testing protocol was statistically significant in its effectiveness to reduce extubation failure rate, without increasing days of intubation, in preterm infants $32^{6}/_{7}$ weeks or less of gestation. Both Eissa et al[6] and Mandhari et al[7] had large sample sizes to ultimately show improved extubation success through the use of a bundle or algorithm.

Dassios et al[5] conducted an adequately powered cohort study, which found pulling tidal volumes more than 4.5 mL/kg as statistically significant for predicting successful extubation of ventilated infants less than 32 weeks of gestational age. Dassios et al[5] also utilized guidelines for considering extubation as well as specific reintubation criteria for consideration. In a small cohort study, Nakato et al[8] found that in premature infants between 24 weeks and 36 weeks $^{6}/_{7}$ days of gestational age, caffeine and continuous positive airway pressure (CPAP) are important in avoiding need for reintubation. Robbins et al[9] found through a cohort study of intubated premature infants less than 27 weeks of gestation, earlier days of life of first extubation attempts were associated with shorter length of stay and decreased likelihood of developing BPD. Spasojevic and Doronjski[10] identified specific associations with extubation failure and identified specific reintubation criteria in a small cohort study of VLBW infants less than 1.5 kg. Dassios et al,[5] Nakato et al,[8] Robbins et al,[9] and Spasojevic and Doronjski[10]—all collectively utilized specific extubation criteria and specific reintubation criteria in cohort studies, to demonstrate improved outcomes for intubated preterm infants.

Overall, the most recent evidence-based practice (EBP) supported that use of an extubation readiness guideline for preterm infants aids in a decreased number of ventilator days. It was based upon 7 collective sources of levels I to IV, grade A to C evidence, obtained via PubMed, use of a standardized extubation readiness guideline: decreased ventilator days, reduced unnecessary adverse effects of prolonged mechanical ventilation, included specific criteria for extubation, improved postextubation evaluation and management, improved extubation safety, and improved rates of extubation success or avoided need for reintubation.[4-10]

RATIONALE

A standardized approach to extubation has been linked to decreased ventilator days, reduced unnecessary adverse effects of prolonged mechanical ventilation, improved postextubation evaluation and management, improved extubation safety, and improved rates of extubation success or avoidance of the need for reintubation.[4-10] In the preimplementation period, this NICU lacked a standardized guideline to address extubation readiness and the extubation process for preterm infants $32^{6}/_{7}$ weeks or less of gestation. Evaluation of extubation readiness was at the discretion of the individual provider. The preimplementation process state is displayed in Supplemental Figure 1, available at http://links.lww.com/ANC/A250, while the desired state with the intervention is displayed in Supplemental Figure 2 (http://links.lww.com/ANC/A251).

As displayed in Supplemental Figure 3, the theory of planned behavior by Ajzen (available at http://links.lww.com/ANC/A252) placed focus on attitudes toward the behavior, subjective norms, and perceived behavioral control. A central factor in this theory was that an individual's intention to perform a given action is influenced by motivational behaviors.[1] For this QI project, motivational tactics to promote use of the new guideline included data reporting, presence of change champions on the unit, and educational visuals. Ajzen also noted in this theory that opportunities and resources often contribute to the success of the performed behavior.[11] The extubation readiness guideline included prompts and reminders to initiate team decision-making and options to consider for extubation (Figure 1). The guideline also listed references utilized for relevant EBP support. In the theory of planned behavior, Ajzen further mentioned that intentions and perceptions of control interact in the prediction of behavior.[11] It is noted in the theory that

TABLE 1. Synthesis Table

Level of Evidence	Studies, n	Summary of Findings	Overall Quality
1	1	Ferguson at al[4] found that for preterm infants <37-wk gestation, noninvasive respiratory support is beneficial post-extubation and methylxanthines reduce extubation failure. Corticosteroids and chest physiotherapy for preterm infants <37-wk gestation may be associated with significant adverse effects and questionable safety. With the use of a random-effects model, corticosteroids did not reduce reintubation for preterm infants <37-wk gestation. Doxapram does not aid in successful extubation for preterm infants <37-wk gestation.	*B:* SR and meta-analysis with extensive search strategy, specific inclusion/exclusion criteria, and RCTs included. Utilized pooled data and past Cochrane reviews. Overall consistent results and measures. Clear, consistent recommendations, as well as recommendations for future research.
4	6		*All: All were cohort studies or quality improvement projects with no randomization and no control.* *B's: All had larger sample sizes. Dassios et al[5] reported adequate power. Results consistent and recommendations clear.*
		Eissa et al[6] found that the use of an extubation bundle with modified SBT, prior to elective extubation, was useful in predicting successful extubation in preterm infants ≤30-wk gestation.	*B:* Quality improvement project with use of a guideline and algorithm. Various statistical tests were used for analysis.
		Mandhari et al[7] found that a 2-stage extubation readiness testing protocol was effective in reducing extubation failure rate, without increasing days of intubation, in preterm infants ≤$32^{6}/_{7}$ wk.	*B:* Specific exclusion criteria, protocol, and defined parameters were utilized. Multiple statistical tests were used for analysis. Future studies are needed on older infants.
		Dassios et al[5] found that V_T > 4.5 mL predicted successful extubation of ventilated infants <32-wk gestational age. Both centers utilized guidelines for considering extubation.	*B:* 2-center study. Predictive ability of the V_T method classified as moderate. No data were collected regarding infection in the cohort, so it is possible that sepsis may have impacted the outcome of extubation (confounding variable). This was the first study to investigate relation between V_T during weaning/extubation.
			C's: All had no power analysis reported.
		Nakato et al[8] found that in premature infants 24 wk to 36 wk 6 d gestational age, caffeine and CPAP are important in avoiding need for reintubation. Pressure values (PEEP and plateau pressure), arterial blood gases, and capnometry are important parameters to evaluate in the weaning and extubation process.	*C:* Small sample size (hospital strike and NICU reform made it impossible to obtain a larger sample size). Hospital in Brazil (possibly limits credibility). Recommendations clear and consistent with previous research.
		Robbins et al[9] found that in intubated premature infants <27-wk gestation, earlier day of life of first extubation attempt was associated with shorter length of stay and decreased likelihood of developing BPD.	*C:* Limited to extremely premature infants (possible threat to generalizability). The results were consistent and recommendations were clear.
		Spasojevic and Doronjski[10] found that in VLBW newborns (<1500 g) subjected to mechanical ventilation; male gender, lower birth weight, Apgar scores, and lower weight at extubation were associated with extubation failure. V_T, SpO_2/FiO_2 ratio, SBT, and SAS scores 1 h post-extubation and later might be valuable in identifying patients at risk to fail extubation.	*C:* Limited to VLBW newborns (possible threat to generalizability). Recommendations clear and consistent with previous research, but future research still recommended.

Abbreviations: BPD, bronchopulmonary dysplasia; CPAP, continuous positive airway pressure; NICU, neonatal intensive care unit; PEEP, positive end-expiratory pressure; RCT, randomized controlled trial; SAS, sedation agitation scale; SBT, spontaneous breathing trial; SpO_2/FiO_2, oxygen saturation/fraction of inspired oxygen; SR, systematic review; VLBW, very low birth weight; V_T, tidal volume.

FIGURE 1

Extutbation Readiness Guideline	
Guideline Inclusion Criteria Intubated premature infant ≤32 6/7 weeks GESTATIONAL AGE	**Guideline Exclusion Criteria** -Known complex/extensive cardiac defect (i.e. tetralogy of fallot (TOF), dextrocardia, coarctation of the aorta, double aortic arch, double outlet right ventricle, double inlet left ventricle, Ebstein's anomaly, hypoplastic left heart, hypoplastic right heart, tricuspid atresia, pulmonary atresia, total anomalous pulmonary venous return, transposition of the great arteries, vascular ring, etc.) -Known congenital craniofacial anomaly (i.e. Pierre Robin, cleft palate, cystic hygroma, etc.) -Known neurological syndrome/defect or other syndrome affecting respiratory status (i.e. spinal muscular atrophy (SMA), congenital central hypoventilation syndrome, cystic fibrosis (CF), Down Syndrome, anencephaly, etc.) -Known airway abnormality (i.e. congenital pulmonary airway malformation (CPAM), congenital diaphragmatic hernia (CDH), tracheoesophageal fistula (TEF), tracheomalacia, etc.)
Guideline for Extubation	
1. Extubation Readiness Assessment -Review sedation weaning plan[2,3,9] -Ensure patient is no longer on paralytic medications[1] -Ensure stable temperature[3] -Ensure stable vital signs[3] -Ensure hemodynamic stability[1,9] -Discuss the extubation readiness plan with team on morning rounds o If ALL Extubation Readiness Criteria are met, obtain an order in EPIC for extubation (utilize Extubation Order set) **2. Extubation Readiness Criteria** -Most Recent Blood Gas o pH >7.25[5] -FiO2 Requirement o <40% FiO2[5] -RR o Patient has respiratory effort above the set rate on the ventilator[2,5,6,9] -Presence of a gag/cough[1,5,6]	**3. Caffeine Citrate** -Consider a loading dose of Caffeine prior to extubation at the provider's discretion (especially for patients who have never received Caffeine)[2,4,10] **4. Immediately Prior to Extubation** -An extubation order should be written in EPIC by the Provider (utilize Extubation Order set) -The Bedside Nurse (RN), Charge RN, Provider, and Respiratory Therapist (RT) should be present at the bedside for the extubation[1,8] -Prepare non-invasive respiratory support (i.e. CPAP, HNC)[1,4,8,10] -Ensure proper emergency equipment and intubation supplies are at the bedside[1] -Aspirate residual stomach contents from the NG/OG tube immediately prior to extubation[10] o For patients on continuous feeds- stop feeds 1 hour prior to extubation and aspirate any residual stomach contents from the NG/OG tube immediately prior to extubation as well[10] -Suction infant via ETT and/or orally if indicated[10] -Strict minimal handling/hands off as much as possible[10] -Assure order from Provider written in EPIC for new non-invasive respiratory support (utilize Extubation Order set)
Post Extubation -Strict minimal handling/hands off as much as possible[10] -Obtain a follow up blood gas[8] **Post Extubation Reportable Events** -Greater than 6 apnea episodes requiring tactile stimulation in 6 hours[9] -Frequent apneas[6] -Apnea episode requiring positive pressure ventilation (PPV)[8,9] -Sustained FiO_2 requirement >60%[9] -Excessive work of breathing and severe retractions[8] -pH <7.25[8,9]	**Required Documentation** -RN to document monitor vital signs at time of extubation, 15 minutes post extubation, and 1 hour post extubation[1] -RN to document any changes in vital signs or concerning events indicating need for reintubation -RN to notify Provider and RT with any concerns for need for reintubation -RT to separately document time of extubation

Extubation readiness guideline. Guideline implemented.[4-10,12-14]

the greater the favorable social pressure and the greater the perceived behavioral control, the greater the intention to perform a given behavior.[11] For this QI project, education regarding the guideline was presented to all staff at the same time to create equal opportunity and group consensus. Change champions also served as key personnel in promoting favoritism of the guideline. The guideline further allowed for behavior control, as some of the elements in the guideline remained at the discretion of the provider. A modified figure of Ajzen's theory, with applicability to the implemented guideline, is shown in Supplemental Figure 4, available at: http://links.lww.com/ANC/A253.

As presented in Supplemental Figure 5 (available at: http://links.lww.com/ANC/A254), the framework for complex innovations described by Helfrich et al[15] focused on innovation, champions, management support, available financial resources, implementation policies and practice, implementation climate, and implementation effectiveness. Helfrich et al[15] emphasized coordinated use of complex innovations by multiple organization members. For this QI project a committee was formed to create a strong communication network involving champions, management, and various levels of staff. Best practice literature supported the implementation of a guideline into practice, an implementation climate of shared importance for the change, and goal achievement. Employee training was emphasized to achieve buy-in for the necessity of the guideline (see Supplemental Figure 6, available at: http://links.lww.com/ANC/A255). Helfrich et al[15] additionally discussed the need for prioritizing roles or tasks within the organization. For this QI project, the assigned nurse (RN) held primary responsibility in completing the bedside checklist, to engage team members in guideline use and adherence (Figure 2). Providers, respiratory therapists (RTs), and nursing held joint responsibility in reviewing guideline criteria, ensuring extubation preparation, and expressing any patient concerns. These efforts created joint initiatives for a collective vision and goal of timely and appropriate extubation. A modified figure of Helfrich's Framework, specific to this QI project, is displayed in Supplemental Figure 7, available at: http://links.lww.com/ANC/A256.

SPECIFIC AIMS

The purpose of this QI project was to implement and evaluate the effectiveness of an extubation readiness guideline in preterm infants $32^6/_7$ weeks or less of gestation in a mid-Atlantic level IV NICU, with the intention to reduce ventilator days for this population.

METHODS

Context

This 49-bed level IV NICU provides 24-hour care to infants 23 weeks of gestational age to 1 year of age. This unit employs approximately 150 NICU nurses, 32 NICU respiratory therapists, as well as 48 designated NICU providers (21 attendings, 18 nurse practitioners, and 9 fellows). For this QI project, intubated preterm infants $32^6/_7$ weeks or less of gestational age were included. To avoid contributing factors and inconsistencies, exclusion criteria included: complex/extensive cardiac defect, congenital craniofacial anomaly, neurological syndrome or other syndrome affecting respiratory status, and known airway abnormality. Infants intubated solely to receive in-and-out surfactant, intubated for less than 22 hours, infants with an unplanned

FIGURE 2

Checklist for Extubation Readiness Guideline					
Patient Name: **Patient MRN:** **Bedside RN completing checklist:**					
	Check One			**Comments (Required for Any No's)**	
	Yes	**No**	**N/A**	**Comments if No Chosen**	Other Comments
Patient Inclusion Criteria Met for Guideline Utilization					
Sedation Reviewed					
Paralytics Discontinued					
Vital Signs Reviewed					
Patient Hemodynamically Stable					
Extubation Plan Discussed on Rounds					
Blood Gas Criteria Met					
FiO2 Requirement Met					
Patient Respiratory Rate Above Set Rate on Ventilator					
Caffeine Use Discussed					
Gag/Cough Present					
Extubation Order Obtained					
Required Staff Present for Extubation					
Equipment and Supplies Present at Bedside for Extubation					
Patient Suctioned (mouth, nares, ETT, other)					
Stomach Contents Aspirated and/or Feedings Paused					
Minimal Patient Handling					
Follow-up Blood Gas Obtained					
Order Obtained for New Non-Invasive Respiratory Support (if patient requires)					
Documentation Completed					
Provider Informed of Any Reportable Events					
LEAVE COMPLETED CHECKLIST IN PATIENT BEDSIDE CHART (BLUE BEDSIDE CHART)					

Bedside nursing checklist data collection form. Paper document.

extubation(s), and intubated infants meeting criteria but transferred to another facility were also excluded.

Intervention

The evidence-based intervention implemented for this QI project was an extubation readiness guideline, created by a multidisciplinary committee (RTs, RNs, nursing leadership, and providers) (Figure 1). The key elements included in the guideline were: patient inclusion/exclusion criteria, sedation review, vital sign analysis, blood gas and oxygen requirement threshold, caffeine use, patient assessment, provider orders, feeding recommendations, equipment and staff preparation, minimal patient handling, documentation, and patient follow-up and reportable events. Led by the QI project lead (QI-PL), the multidisciplinary committee was utilized to: develop the guideline specific to this NICU's needs, facilitate staff education, perform electronic health record (EHR) chart audits (see Supplemental Appendix 2, available at: http://links.lww.com/ANC/A245), and develop a team of unit-based champions. The unit's preimplementation process is displayed in Supplemental Figure 1 (available at: http://links.lww.com/ANC/A250), while the desired state with the intervention (postimplementation process) is displayed in Supplemental Figure 2 (available at: http://links.lww.com/ANC/A251). The preimplementation (6 weeks) and postimplementation periods (11 weeks) of this QI project occurred over a 17-week period in the fall of 2021.

Study of the Intervention

Preimplementation and postimplementation data comparisons were performed for assessing the impact of the intervention and establish whether the observed outcomes were due to the intervention.

MEASURES

Structure, process, and outcome measures used to track implementation progress and impact included: staff education completion, guideline availability, guideline use, ventilator days, time to first extubation, patients intubated for more than 28 days, and need for reintubation (see Supplemental Appendix 3, available at: http://links.lww.com/ANC/A246). Initial implementation strategies and tactics included: an educational staff PowerPoint (see Supplemental Appendix 4, available at: http://links.lww.com/ANC/A247), an educational posttest (see Supplemental Appendix 5, available at: http://links.lww.com/ANC/A248), committee formation with project champions, and committee meetings. Postimplementation strategies and tactics included: committee meetings, unit signage (see Supplemental Figure 6, available at: http://links.lww.com/ANC/A255), bedside visuals and catchy slogans, e-mail reminders, staff newsletter notices with visuals (see Supplemental Figure 6, available at: http://links.lww.com/ANC/A255), staff meeting announcements, food and treats, safety work group meeting presentations, guideline uploading into the unit SharePoint site, additional copies of relevant forms in a storage room for champions to distribute and access if necessary, direct verbal feedback, and a hard copy of the guideline at every patient bedside in the bedside reference. Additional strategies and tactics added toward the end of project postimplementation (to promote continued guideline adherence) included e-mailed meeting minutes, paper copies of the guideline and bedside checklist placed in the bedside rounding script folder for applicable patients, assistance from the rounding nurse, and use and presentation of run charts and data. Specific adjustments to strategies and tactics during postimplementation included: the addition of more eye-catching visuals, individually targeted e-mail reminders and feedback, and weekly communication with champions.

ANALYSIS

Individual chart audits performed by the QI-PL, in a private locked office, were used as the primary patient data collection method. Recorded patient information included: patient coded/assigned number, gestational age, corrected age, birth weight, current weight, gender, ventilator days, days to first extubation attempt, need for reintubation, checklist received, guideline used, patient qualified for guideline use, and exclusion diagnosis if applicable (see Supplemental Appendix 3, available at: http://links.lww.com/ANC/A246). Staff education data, patient data, and the chart audit data were all completed and analyzed weekly by the QI-PL in an Excel data management file, on a password-protected and encrypted computer (see Supplemental Appendix 3, available at: http://links.lww.com/ANC/A246). Run charts were used to analyze data on a weekly basis to identify trends.

ETHICAL CONSIDERATIONS

All data entered into the Excel file were coded, for patient and staff privacy protection. The Checklist for Extubation Readiness Guideline Use, the Champion Chart Audit Tool for Extubation Readiness Guideline Use, and the Patient Code Key and Staff Code Key were completed as paper documents (see Supplemental Appendix 6, available at: http://links.lww.com/ANC/A249). These paper documents were stored in a private locked office in a locked cabinet. All paper documents were destroyed at project completion. This project was approved by both university and hospital institutional review boards and deemed nonhuman subjects QI.

RESULTS

For 2021 this NICU had 11.5% of VLBW infants on a ventilator for more than 28 days, compared with a median of 14.2% infants (in this subgroup) in other similar NICUs throughout the United States.[3] Since 2015, this was the first time this NICU dropped below the median for this statistic. In regard to BPD in 2021, this NICU had a 36% incidence of BPD in infants less than 33 weeks of gestational age and of VLBW versus a 31% median incidence of BPD in other similar NICUs throughout the United States (in the subgroup)[3] (see Supplemental Figure 14, available at: http://links.lww.com/ANC/A257, displays the 2020 and 2021 Vermont Oxford Network [VON] data comparisons).[3]

Based on 6 weeks of preimplementation EHR chart audits of the 9 eligible patients in this NICU, 44% of preterm infants $32^6/_7$ weeks of less of gestation were intubated for more than 28 days, averaged 23 days on a ventilator, averaged 22 days to the first extubation attempt, and 11% required reintubation within 72 hours (n = 1) (Table 2).

Post-implementation, a positive trend in rolling education completion was indicated by 78% of staff completing education by project completion (see Supplemental Figures 8 and 9, available at: http://links.lww.com/ANC/A258 and http://links.lww.com/ANC/A259). The target project goal for education completion was 100%. Post-implementation, the guideline was utilized and a checklist was received for 100% of the 6 applicable patients (see Supplemental Figure 10, available at: http://links.lww.com/ANC/A260). Postimplementation adherence with guideline use, obtained via EHR chart audits by the QI-PL, was 91% (see Supplemental Figure 11, available at: http://links.lww.com/ANC/A261). The target goals for guideline utilization, checklist completion, and guideline adherence were 100%. Post-implementation, of the 6 eligible patients, 33% of preterm infants $32^6/_7$ weeks or less of gestation were intubated for more than 28 days, averaged 22 days on a ventilator, averaged 18 days to first extubation attempt, and 33% required reintubation within 72 hours (n = 2) (Table 2). There was a decrease in need for: intubation for more than 28 days, average total ventilator days, and days to first extubation attempt post-implementation. Post-implementation, there was a slight increase in the need for reintubation. The target goals for all of these outcome measures were 0 day or 0%. As displayed via the run chart, weeks 14 through 17 of the post-implementation period began to display a decreased percentage of days to first extubation attempt versus total ventilator days for patients, associated with earlier attempts at first extubation (see Supplemental Figure 12, available at: http://links.lww.com/ANC/A262). More specifically, during the postimplementation period, preterm infants between 28 and $32^6/_7$ weeks of gestational age averaged 3 days on a ventilator, amarked improvement (Table 2 and see Supplemental Figure 13, available at: http://links.lww.com/ANC/A263).

Facilitators in achieving intended outcomes included the strategies and tactics previously mentioned. Improved champion communication, assistance from the rounding nurse, and continued distribution of the guideline were particularly helpful in sustaining: checklist completion, guideline adherence, improved patient outcomes, and project interest.

DISCUSSION

Summary

Key findings for the targeted population in this QI project were an associated decrease in: total ventilator days, length of intubation for more than 28 days, and average days to first extubation attempt post-implementation (see Supplemental Figure 13, available at: http://links.lww.com/ANC/A263). Particularly, a notable decrease by 22 ventilator days, for preterm infants between 28 and $32^6/_7$ weeks of gestational age,

TABLE 2. Patient Outcome Data

	Preimplementation (n = 9)	Postimplementation (n = 6)
Mean total ventilator days	23 (n = 9)	22 (n = 6)
Mean days to first extubation attempt	22 (n = 9)	18 (n = 6)
Percentage of infants intubated > 28 d	44% (n = 4)	33% (n = 2)
Percentage of very low birth-weight infants (<1.5 kg) intubated > 28 d	50% (n = 4)	50% (n = 2)
Mean ventilator days <28-wk gestational age subgroup	22 (n = 5)	32 (n = 4)
Mean ventilator days 28-$32^6/_7$-wk gestational age subgroup	25 (n = 4)	3 (n = 2)
Mean days in the NICU (excluding those who remained in the NICU at project completion)	79 (n = 8)	26 (n = 3)
Percentage of infants requiring reintubation within 72 h	11% (n = 1)	33% (n = 2)

Abbreviation: NICU, neonatal intensive care unit.

TABLE 3. Infant Chart Audit Data

	Preimplementation (n = 9)	Postimplementation (n = 6)
Provider present at bedside for extubation	44% of the time (n = 9)	50% of the time (n = 6)
Extubation order placed	44% of the time (n = 9)	100% of the time (n = 6)
Charge RN present at bedside for extubation	0% of the time (n = 9)	17% of the time (n = 6)
Nursing and respiratory documented the same time of extubation	33% of the time (n = 9)	33% of the time (n = 6)
Oxygen requirement <40%	89% of the time (n = 9)	83% of the time (n = 6)
Last blood gas with pH >7.25	100% of the time (n = 9)	83% of the time (n = 6)
Not on paralytics at time of extubation	100% of the time (n = 9)	100% of the time (n = 6)
Caffeine citrate ordered at any point	100% of the time (n = 9)	100% of the time (n = 6)
Caffeine citrate ordered prior to extubation if applicable	50% of the time (n = 6)	83% of the time (n = 5)
Follow-up blood gas obtained	100% of the time (n = 9)	100% of the time (n = 6)
Noninvasive support documented	100% of the time (n = 9)	100% of the time (n = 6)

Abbreviations: RN, registered nurse.

was seen post-implementation. Strengths of the implemented guideline included the incorporation of: pharmacological interventions, nonpharmacological interventions, teamwork, patient assessment, and outlined procedures and criteria into a single point of reference. Caffeine administration prior to extubation for applicable patients, for example, was notably improved post-implementation through guideline use and adherence (Table 3).

Interpretation

This QI project showed improvement in length of intubation through use of a guideline. This finding is consistent with available literature that demonstrates use of specific criteria for successful extubation of the neonate (in a bundle, parameters, or protocols).[6-8] Although need for reintubation increased during the postimplementation period, this was 1 patient pre-implementation versus 2 patients post-implementation, due to the small number of patients acquired for this QI project. However, literature does suggest that early first extubation attempts reduce length of stay, even if reintubation is necessary.[9]

Limitations

The small number of patients observed pre- and post-implementation limited overall associations, as well as anticipated outcomes for this QI project. Statistical significance was not explored. The small sample size, QI nature of this project, and project timeline limited the generalizability of all project findings. However, patient demographics were very similar pre- and post-intervention (Table 4), allowing for general comparisons by gestational age, pre- and post-intervention. Additionally, as previously mentioned, information recorded by bedside nursing on the paper checklists was often inaccurate when compared with patient EHR documentation. Bedside nursing often reported that vital signs were documented per guideline recommendations, when in fact this documentation was not recorded in the EHR. Bedside nursing also inaccurately reported laboratory values, including last recorded pH and patient oxygen requirement in the her. Possible explanations for these inaccuracies may have included the high patient acuity and ongoing staffing shortages in this NICU. Other project barriers included: staff turnover, competing unit projects, the use of paper documents, the large number of NICU staff to education, and patient acuity.

CONCLUSIONS

A standardized guideline for extubation readiness may reduce number of ventilator days, days to first extubation attempt, and need for intubation for more than 28 days, for infants $32^6/_7$ weeks or less of gestation in the NICU. The number of ventilator days can be decreased in infants 28 to 32 weeks of gestation. Ongoing staff education, multidisciplinary cooperation, and EHR audits for guideline compliance are necessary for long-term change and sustainability. EHR integration, with a trigger of the guideline for referencing on applicable patients, is essential to promote use, ease of use, and awareness of the guideline. Use of a bedside paper checklist may not be a sustainable practice, as staff notations were often conflicting or inaccurate when reviewing data in the patient's EHR. Paper checklists also risk becoming misplaced. Please see the Summary of Recommendations Table for additional insight on: what we know, what needs to be studied, and what we can do today.

Mechanisms for project sustainability include: continual guideline revisions from staff feedback and new EBP, keeping the hard copy of the guideline at every patient bedside in the bedside reference,

TABLE 4. Infant Demographics

	Preimplementation (n = 9)	Postimplementation (n = 6)
<1.5 kg at birth	89% (n = 8)	67% (n = 4)
<1.5 kg at time of first extubation attempt	67% (n = 6)	67% (n = 4)
Male	44% (n = 4)	50% (n = 3)
<28-wk gestational age male	22% (n = 2)	17% (n = 1)
28-32$^{6}/_{7}$-wk gestational age male	22% (n = 2)	33% (n = 2)
Female	56% (n = 5)	50% (n = 3)
<28-wk gestational age female	33% (n = 3)	50% (n = 3)
28-32-$^{6}/_{7}$ wk gestational age female	22% (n = 2)	0% (n = 0)
28-32-$^{6}/_{7}$ wk gestational age	44% (n = 4)	33% (n = 2)
<28-wk gestational age	56% (n = 5)	67% (n = 4)
<28-wk corrected age at time of first extubation attempt	22% (n = 2)	17% (n = 1)
Overall mean birth weight	0.836 kg (n = 9)	1.085 kg (n = 6)
Overall mean weight at time of first extubation attempt	1.171 kg (n = 9)	1.308 kg (n = 6)
Overall mean gestational age	27 wk (n = 9)	28 wk (n = 6)
Overall mean corrected age at time of first extubation attempt	30$^{2}/_{7}$ wk (n = 9)	31 wk (n = 6)

educate new hires, allowing all staff members access to the guideline on the unit SharePoint site, QI-PL and champion presence on the unit, and work group continuation. Future projects and follow-ups are necessary to explore extubation readiness in the NICU, as well as reduction in annual BPD rates. Relevant annual VON data will be reviewed and shared as available. Reporting of relevant outcome data to staff should be continued annually, at a minimum. Shifting guideline ownership into a previously established workgroup would be recommended for similar projects as well.

Summary of Recommendations for Practice and Research

What we know:

- Longer duration of mechanical ventilation increases an infant's risk for bronchopulmonary dysplasia (BPD)
- Noninvasive respiratory support is beneficial post-extubation
- Methylxanthines reduce extubation failure
- A standardized approach to extubation has been linked to decreased ventilator days, reduced unnecessary adverse effects of prolonged mechanical ventilation, improved postextubation evaluation and management, improved extubation safety, and improved rates of extubation success or avoidance of the need for reintubation
- Utilization of specific extubation criteria and specific reintubation criteria improves outcomes for intubated preterm infants
- Early first extubation attempts reduce length of stay, even if reintubation is necessary

What needs to be studied:

- Additional criteria to include for extubation readiness of the preterm infant in the NICU
- Additional use of an extubation readiness guideline in a larger number of NICU patients remains ideal for analyses of statistical significance
- Comparisons of BPD rates, ventilator days, days to first extubation attempt, and reintubation pre- and post-implementation of an extubation readiness guideline for preterm infants over a longer period (ideally annually)

What we can do today:

- Utilize a standardized guideline for extubation readiness in the NICU
- Monitor staff adherence to a standardized NICU extubation readiness guideline through EHR chart audits, as opposed to paper checklists
- Provide ongoing staff education and multidisciplinary team cooperation for extubation readiness in the NICU
- Integrate a standardized guideline for extubation readiness in the NICU into the EHR
- Provide continual guideline revisions from staff feedback and new EBP
- Utilize a previously established workgroup for guideline ownership
- Aim to improve long-term respiratory outcomes for preterm infants

References

1. National Heart, Lung, and Blood Institute. Respiratory Distress Syndrome. https://www.nhlbi.nih.gov/health-topics/respiratory-distress-syndrome.
2. National Organization for Rare Disorders. Bronchopulmonary Dysplasia. https://rarediseases.org/rare-diseases/bronchopulmonary-dysplasia-bpd/#:~:text=Bronchopulmonary%20dysplasia%20can%20affect%20both,the%20lower%20the%20birth%20weight. Published 2018.
3. Vermont Oxford Network (VON) Database. 2011-2021.
4. Ferguson KN, Roberts CT, Manley BJ, Davis PG. Interventions to improve rates of successful extubation in preterm infants a systematic review and meta-analysis. *JAMA Pediatr*. 2017;171(2):165-174. doi:10.1001/jamapediatrics.2016.3015.
5. Dassios T, Williams E, Ambulkar H, Shetty S, Hickey A, Greenough A. Tidal volumes and outcome of extubation in mechanically ventilated premature infants. *Am J Perinatol*. 2020;37(2):204-209. doi:10.1055/s-0039-1696714.
6. Eissa A, Rifai HA, Abdelmaaboud M, et al. Use of extubation bundle including modified spontaneous breathing trial (SBT) to reduce the rate of reintubation, among preterm neonates ≤ 30 weeks. *J Neonatal Perinatal Med*. 2020;13(3):359-366. doi:10.3233/NPM-190236.
7. Mandhari HA, Finelli M, Chen S, Tomlinson C, Nonoyama ML. Effects of an extubation readiness test protocol at a tertiary care fully outborn neonatal intensive care unit. *Can J Respir Ther*. 2019;55:81-88. doi:10.29390/cjrt-2019-011.
8. Nakato AM, Cavalcante da Silva R, Filho NR. Analysis of respiratory behavior and clinical parameters for successful extubation in premature infants. *Int J Pediatr*. 2018;6(9, serial number 57):8215-8223. doi:10.22038/ijp.2018.31384.2774.
9. Robbins M, Trittmann J, Martin E, Reber KM, Nelin L, Shepherd E. Early extubation attempts reduce length of stay in extremely preterm infants even if re-intubation is necessary. *J Neonatal Perinatal Med*. 2015;8(2):91-97. doi:10.3233/NPM-15814061.
10. Spasojevic S, Doronjski A. Risk factors associated with failure of extubation in very-low-birth-weight newborns. *J Matern Fetal Neonatal Med*. 2018;31(3):300-304. doi:10.1080/14767058.2017.128588.
11. Ajzen I. The theory of planned behavior. *Organ Behav Hum Decis Process*. 1991;50(2):179-211. doi:10.1016/0749-5978(91)90020-T.
12. American Association of Respiratory Care. AARC clinical practice guideline removal of the endotracheal tube—2007 revision and update. *Resp Care*. 2007;52(1):82-93. https://www.aarc.org/wp-content/uploads/2014/08/removal_of_endotracheal_tube.pdf.
13. Sant'Anna GM, Kesler M. Weaning infants from mechanical ventilation. *Clin Perinatol*. 2012;39(3):543-562. doi:10.1016/j.clp.2012.06.003.
14. West G, Pope A. Factors promoting successful extubation: an audit of planned extubations in preterm infants following the implementation of nursing guidelines. *J Neonatal Nurs*. 2010;16(6):267-273. https://www.doi.org/10.1016/j.jnn.2010.07.019.
15. Helfrich CD, Weiner BJ, McKinney MM, Minasian L. Determinants of implementation effectiveness: adapting a framework for complex innovations. *Med Care Res Rev*. 2007;64(3):279-303. doi:10.1177/1077558707299887.