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Overcoming Barriers to Oxygen Saturation Targeting

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ABSTRACT

OBJECTIVE. To reduce hyperoxia in very low birth weight infants who receive supplemental oxygen, the Children's Mercy Hospital neonatal respiratory quality improvement committee introduced the potentially better practice of oxygen saturation targeting and identified strategies to overcome barriers to implementation of this practice.

METHODS. Using rapid-cycle quality improvement projects, this center adapted an oxygen saturation targeting protocol and tracked hourly oxygen saturation as measured by pulse oximetry in very low birth weight infants who received supplemental oxygen.

RESULTS. The percentage of time in the range of 90% to 94% of oxygen saturation as measured by pulse oximetry increased from 20% to an average of 35% after implementation of the protocol. The percentage of time with oxygen saturation as measured by pulse oximetry >98% dropped from 30% to an average of 5% to 10%.

CONCLUSIONS. A well-planned strategy for implementing oxygen saturation targeting can result in a sustained change in clinical practice as well as change in the culture of the NICU regarding the use of oxygen.

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Key Words

oxygen saturation targeting, quality improvement, very low birth weight, retinopathy of prematurity, chronic lung disease

Abbreviations

SpO₂—oxygen saturation as measured by pulse oximetry
STOP-ROP—Supplemental Therapeutic Oxygen for Prethreshold Retinopathy of Prematurity
BOOST—Benefits of Oxygen Saturation Targeting
VLBW—very low birth weight
ROP—retinopathy of prematurity
QI—quality improvement
PBP—potentially better practice
FAQ—frequently asked question
FiO₂—fraction of inspired oxygen
NNP—neonatal nurse practitioner
PPHN—persistent pulmonary hypertension
RN—registered nurse
RT—respiratory therapist

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SINCE THE ADVENT of pulse oximetry, the measurement of arterial pulse oxygen saturation level (SpO₂) has been used as a noninvasive estimation of the adequacy of oxygenation. At best, pulse oximetry can alert the clinician to a potential range of Pao₂ that an infant may be experiencing, because the correlation between SpO₂ and Pao₂ varies considerably between infants.¹⁻³ The sigmoid shape of the oxygen dissociation curve results in large changes in Pao₂ in the upper portion of the curve with minimal changes in oxygen saturation of hemoglobin.^{2,4} The range of Pao₂ values that can occur at a given SpO₂ value becomes large at higher saturation values.^{2,3,5}

Earlier reviews of pulse oximetry warn of the difficulty of assessing both hypoxemia and hyperoxemia by pulse oximetry alone and suggest that pulse oximetry should not be used exclusive of Pao₂ measurements to manage blood oxygenation.^{2,5} In most NICUs, pulse oximetry gradually replaced transcutaneous Po₂ instrumentation, and arterial blood gases were checked less frequently to avoid the complications from indwelling arterial catheters and arterial punctures. The sensitivity and the specificity of pulse oximeters to detect hyperoxemia varies among models. An upper saturation limit of no more than 95% is required to detect a majority of elevated Pao₂ values.^{4,5} Although most clinicians would agree to the merits of avoiding hyperoxia, the practice of many NICUs has evolved to accept SpO₂ of 98% to 100% in infants who receive supplemental oxygen regardless of gestational age or the disease process that precipitated the use of oxygen.⁶ Whereas most NICUs set a lower alarm limit to provide an auditory alert to impending hypoxia, the habit of many units is to set a high alarm limit of 98% to 100%⁶ or not to set an upper auditory alarm at all. This evolution in clinical practice with the unquestioned use of pulse oximetry for the assessment of oxygenation has resulted in the desensitization of many caregivers to both the potential presence and the hazard of hyperoxia.

Concern regarding the potential benefit or detriment of hyperoxia resulted in 2 multicenter, controlled, randomized, clinical trials: Supplemental Therapeutic Oxygen for Prethreshold Retinopathy of Prematurity (STOP-ROP) and Benefits of Oxygen Saturation Targeting (BOOST).^{7,8} In STOP-ROP and BOOST, very low birth weight (VLBW) infants who required supplemental oxygen were randomly assigned to a conventional or high SpO₂ target range either at the time of diagnosis of prethreshold retinopathy of prematurity (ROP; an average of 35 weeks' postmenstrual age)⁷ or at 32 weeks' postmenstrual age.⁸ The STOP-ROP trial findings demonstrated that high saturation ranges (96%–99%) did not significantly decrease the proportion of infants who had at least 1 eye progress to threshold ROP and had deleterious effects on chronic lung disease in some infants with no change in growth or neuromotor development.⁷

Similarly, the infants who were randomly assigned to high oxygen saturation targeting (95%–98%) in the BOOST trial had no beneficial effect on growth or development. These infants had higher rates of dependence on oxygen at 36 weeks' postmenstrual age and home oxygen therapy.⁸

Retrospective and observational studies suggest that controlling oxygen saturation ranges from birth in VLBW infants may beneficially affect the rate of severe ROP.^{7,9,10} After implementing a strict oxygen saturation protocol beginning from birth, Chow et al¹⁰ observed a significant decrease in the rate of severe ROP compared with historical rates of ROP. These studies suggest that maintaining oxygen saturations in a range to avoid hyperoxia may result in improved ROP and pulmonary outcomes.

The Children's Mercy Hospital neonatal respiratory quality improvement (QI) committee joined with multiple other centers through the Vermont Oxford Network to form The Breathsavers Quality Improvement Exploratory Group, which identified reducing chronic lung disease as a primary objective.¹¹ This center adopted the potentially better practice (PBP) of oxygen saturation targeting by developing a protocol and plan. This article describes this single center's structured QI project of implementing this PBP and expands on the issue of overcoming obstacles to acceptance. The outcome measurement goals were as follows:

- 100% of caregivers aware of the goal to avoid hyperoxia in VLBW infants who require supplemental oxygen
- Saturations in the target range of 90% to 94% >50% of the time
- Saturations <98% >90% of the time

METHODS

This QI project was reviewed by the Children's Mercy Hospitals and Clinics Pediatric Institutional Review Board before submission for publication. A structured QI method, plan-do-study-act,¹² was applied to the introduction and subsequent revision of an oxygen saturation protocol. The following steps were followed: assessment of the problem, literature review, staff assessment, protocol development and tracking tools, education of nursery staff, feedback and frequently asked questions (FAQs), and data collection and use (Table 1). All infants who had birth weights <1500 g and were patients in this center's NICU after May 1, 2003, and receiving supplemental oxygen were monitored prospectively until 100 days of age to monitor the introduction of this protocol as outlined in Appendix 1. Statistics were performed using a simple linear regression model looking for trends of the percentage of time above, within, and below the target oxygen saturation ranges.

TABLE 1 Methods

Method	Key Points
Assessment of the problem	This neonatal section identified the incidence of chronic lung disease and ROP as an area of potential improvement. Oxygen saturation targeting was explored with multiple other centers at the VON 2002 Breathsavers exploratory group.
Literature review	The goal of the literature review was to determine evidence-based recommendations for oxygen saturation range for infants who require oxygen therapy in the NICU. Gaps in understanding regarding the relation among SpO_2 , Pao_2 , and adequacy of oxygenation were identified as subjects for education for residents, nurse practitioners, and nursing staff.
Staff assessment	The QI committee individually interviewed physicians, nurse practitioners, and RTs to solicit answers to the mental model survey. ^{13–15} Select nursing staff reviewed the policy outlined by Chow et al ¹⁰ for input in adapting this protocol.
Protocol development and tracking tools	The committee modified the policy outlined by Chow et al ¹⁰ (using a local consensus-based saturation range and a more detailed approach to alarm responses) to create the oxygen saturation targeting protocol (Appendix 1). A database was developed to assess oxygen saturations documented in QS, the nursery's computer-based charting system (QS Technologies, Inc, Greenville, SC). The oxygen saturation value from the beginning of each hour automatically downloaded from the saturation monitor (Nellcor, Pleasanton, CA) to the QS database and was verified by the bedside nurse for a total of 24 data points per infant per day. A statistical program was constructed to assess the mean daily oxygen saturation, daily oxygen saturation ranges, and percentage of time spent both above and below the target saturation goal and initial alarm ranges. Data were collected for VLBW infants who received supplemental oxygen before and after implementation of the protocol.
Education of NICU staff	The QI committee presented the literature review, results of the survey, proposed oxygen saturation targeting protocol, and pre-intervention daily mean oxygen saturations to the attending physicians, who decided on the target oxygen saturation range of 90% to 94% and alarm limits of 85% and 96%. Before the start date, the protocol was introduced to all caregivers via a unit-wide educational campaign, which included newsletter articles, e-mails, posters in the unit and lounge areas, and in-service lectures. Follow-up e-mails were sent after the implementation. Committee members met at the bedside with nurses who were assigned to VLBW infants to answer questions about applying the protocol to specific patients.
Feedback and FAQs	Implementation of the protocol was met with some resistance and frustration because of the perceived difficulty of applying it to certain situations. Modifications of the protocol in the form of FAQs were sent out as needed while the staff became more comfortable with the protocol.
Data collection and use	The daily mean oxygen saturation range was calculated for each VLBW patient who received supplemental oxygen for the first 100 days of life. Oxygen saturation ranges for all infants were combined, averaged, and graphed weekly for an ongoing assessment of adherence to saturation goal ranges. Cards outlining the target saturation range and alarm limits were placed on the monitor of each VLBW infant who was receiving supplemental oxygen as a reminder of the goals. For infants whose mean oxygen saturations remained consistently higher than the target range, the data were presented to the attending physician, nurse practitioner, and bedside nurse involved in the care to identify obstacles in implementing the protocol. The combined, averaged saturation data were used to identify unit-wide relaxation of adherence to the protocol. In-service sessions were implemented to re-educate staff at these intervals.

VON indicates Vermont Oxford Network; QS, Quantitative Sentinel.

RESULTS

Barriers to implementation of oxygen saturation targeting were identified and targeted (Table 2, Appendix 2). Each week, an average of 8 (range: 5–17) VLBW infants received supplemental oxygen during the first 66 weeks after the protocol was introduced. Before initiation of this project, VLBW infants who received supplemental oxygen were in the SpO_2 range of 90% to 94% only 20% of the time. Since implementation of the protocol, the percentage of time in the SpO_2 range of 90% to 94% increased to >40% ($r^2 = 0.22$, $P < .001$). The percentage of time within a wider range of 85% to 94% increased from 22% before intervention to >55% ($r^2 = 0.22$, $P < .001$; Fig 1A).

The overall percentage of time with $SpO_2 >94%$ has

dropped from 78% to <40% ($r^2 = 0.21$, $P = .001$). Tracking the percentage of time spent with $SpO_2 >94%$ alone overlooked improvement in decreased time spent at higher saturations. Before intervention, VLBW infants who received supplemental oxygen had SpO_2 values of 98% to 100% almost 30% of time. Since implementation of this protocol, the percentage of time with SpO_2 of 98% to 100% decreased to ~5% to 10%, a significant negative trend ($r^2 = 0.36$, $P = .001$; Fig 1B).

Although the first 6 weeks after implementation of the protocol showed a sustained improvement in decreasing the time spent with $SpO_2 >94%$ (Fig 1B), the percentage of time in the goal range and within the alarm limits gradually started to decrease (Fig 1A). Twelve weeks after the start of the protocol, the com-

TABLE 2 Barriers Identified in Implementing Oxygen Saturation Targeting Protocol

Problem	Solution
Lack of buy-in from some physicians who questioned supporting evidence	Circulated key articles and summaries of evidence available
Lack of support from some physicians who questioned improbability of achieving goals	Feedback on ability to achieve goals presented to medical staff as weekly graphs showing time in desired oxygen saturation range
Lack of buy-in from NNPs	Education targeted specifically to NNPs
Protocol not discussed or emphasized during daily work rounds	Respiratory QI committee members involved in rounds to draw attention to issue
Caregiver uncertainty concerning population protocol is targeting	Supplied bedside graphs on each individual patient emphasizing saturation range
Target saturation not promptly identified or readily known for VLBW infants	Placement of brightly colored cards on monitors to identify oxygen saturation target range and alarm range
Alarm limits set higher than necessary	Presence of cards requires alarm limit order to be written in chart
Default alarm limits on bedside monitors not programmed for protocol	FAQ sent out to all staff periodically
Staff desensitized to frequent high and low saturation alarms	Increased education regarding resetting alarm limits when device disconnected
Nurse-to-patient ratios made responding to alarms as outlined in protocol difficult when nursing staff overextended	Cards on monitors serve as reminder
Difficulty in applying protocol to infants on nasal cannula	Continued encouragement and positive feedback
	FAQ reminders
	Involved nursing management on issue
	Working to increase nursing staff available as resource on patients who are difficult to maintain
	Development of nasal cannula standard orders that contain detailed weaning protocol

mittee presented an educational program outlining the importance of oxygen saturation targeting, reviewed the data collected to date, and addressed questions. After this second educational effort, the percentage of time within the target range and alarm limit range improved.

Implementation of the protocol raised the concern of a potential increase of hypoxic episodes. Before intervention, VLBW infants who received supplemental oxygen spent 1% of time with $SpO_2 < 85\%$, and only occasionally did these infants desaturate to $SpO_2 < 70\%$. Since beginning this protocol, the amount of time with $SpO_2 < 85\%$ increased, varying from 5% to 13% of the time; however, this is not a statistically significant trend ($r^2 = 0.04$, $P = .12$). No significant trend was noted in the percentage of time with $SpO_2 < 70\%$ ($r^2 = 0.003$, $P = .64$).

Alternating episodes of hyperoxia and hypoxia adversely affect vascular tone and may play a role in the development of ROP.¹⁰ The saturation protocol was revised to limit severe desaturation events, defined as a sustained $SpO_2 < 70\%$ for >1 alarm cycle on the pulse oximeter (3 minutes' duration), while avoiding rebound hyperoxia. The baseline fraction of inspired oxygen (FIO_2) was doubled to bring the SpO_2 to 85% and then aggressively weaned to within 3% of the baseline FIO_2 . These data also were presented to the nursing staff at the second educational conference to allay concerns about more frequent desaturation events.

Data from individual patients were presented weekly to bedside caregivers to facilitate adherence to and discussion of necessary deviation from the protocol goal and alarm saturation ranges. Although implementation of the protocol helped to bring saturations closer to the goal range (Fig 2 A and B), some patients did not tolerate

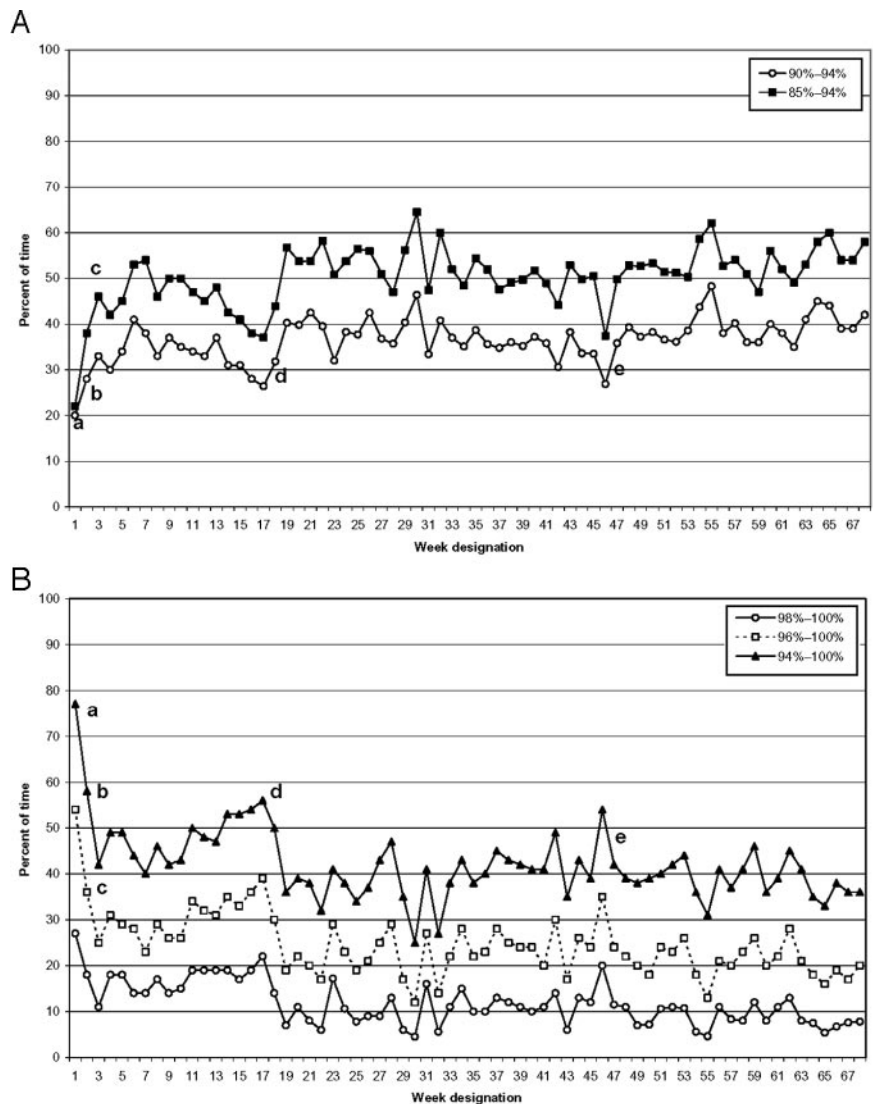
saturations in the low 90s. Bringing these infants into the goal range precipitated frequent and severe desaturations (Fig 2C). These infants' goal and alarm ranges were modified upward to avoid these events.

In response to uncertainty about which infants should follow the oxygen saturation targeting protocol, cards that identify the correct SpO_2 target range and alarm limits were posted on the bedside monitor of each VLBW infant who was receiving supplemental oxygen (concept adapted from Ochsner Clinic Foundation Hospital). The nursery was surveyed regularly to identify the percentage of VLBW infants who were receiving supplemental oxygen and had these cards displayed accurately. These data were used as a measure of awareness of hyperoxia and oxygen saturation targeting. During the first 6 weeks of monitoring card placement, the percentage of correctly placed cards varied from 33% to 78%. Over time, the correct placement of these cards occurred without daily monitoring and reminders and increased to 67% to 100%. There is a statistical correlation with improvement over time ($r^2 = 0.15$, $P = .01$).

DISCUSSION

A well-planned strategy for implementing oxygen saturation targeting can result in a sustained change in both clinical practice and culture of the NICU regarding the use of oxygen. Although the optimal oxygen saturation target range to reduce the potential sequelae of hyperoxia for VLBW infants has not been identified through prospective, randomized trials, this center's neonatal attending staff has accepted the merits of avoiding hyperoxia. The goal of this project was to develop an oxygen saturation targeting protocol that is based on what has been described previously in the literature and to mea-

FIGURE 1
Weekly average values for all infants with birth weight <1500 g at chronological age <100 days. A, Percentage of time spent in range 90% to 94% and 85% to 94%. B, Percentage of time spent with high saturation ranges. ^a Before education concerning oxygen saturation targeting; ^b after education concerning oxygen saturation targeting, before implementation of oxygen saturation protocol; ^c after implementation of oxygen saturation protocol; ^d after second education effort concerning data collected to this point and FAQ; ^e nasal cannula standardized order form implemented.



sure the adherence to that protocol, with the emphasis on implementation of evidence rather than its reproduction.

The oxygen saturation targeting protocol as outlined in Appendix 1 was revised periodically over 18 months to overcome barriers that were identified as the process unfolded. Although any NICU that embarks on a change in SpO_2 targeting will encounter challenges that are unique to its unit, these guidelines may offer suggestions to improve the likelihood of success.

When oxygen saturation targeting first was identified as a PBP for reducing chronic lung disease, the focus initially was on the SpO_2 as the assessment of hyperoxia. In retrospect, a more comprehensive approach could have included strict targeting of Pao_2 values in addition to the SpO_2 for the duration of ready arterial access. This approach could have the added benefit of closely monitoring correlations between Pao_2 and SpO_2 . The ease of use of pulse oximetry has resulted in a subtle shift in

focus from Pao_2 to SpO_2 . A secondary goal has been to educate all caregivers about the limitations of pulse oximetry as the assessment of oxygenation.

The mental model survey¹³⁻¹⁵ identified specific areas of education to be targeted to implement an oxygen saturation targeting protocol successfully. Conducting this survey as a 1-on-1 interview revealed detailed, useful information for the initial stages of protocol planning. In addition, the nursing review of the protocol by Chow et al¹⁰ provided useful feedback that aided in educating nursing staff about how to respond to various scenarios.

The proposed protocol in Appendix 1 was presented to the attending physicians during a regularly scheduled clinical research meeting. The SpO_2 target range of 90% to 94% and alarm limits of 85% to 96% were decided at this meeting, although this was not a unanimous decision. A more systematic approach to reaching consensus among attending physicians regarding target saturation range may have resulted in improved support for the

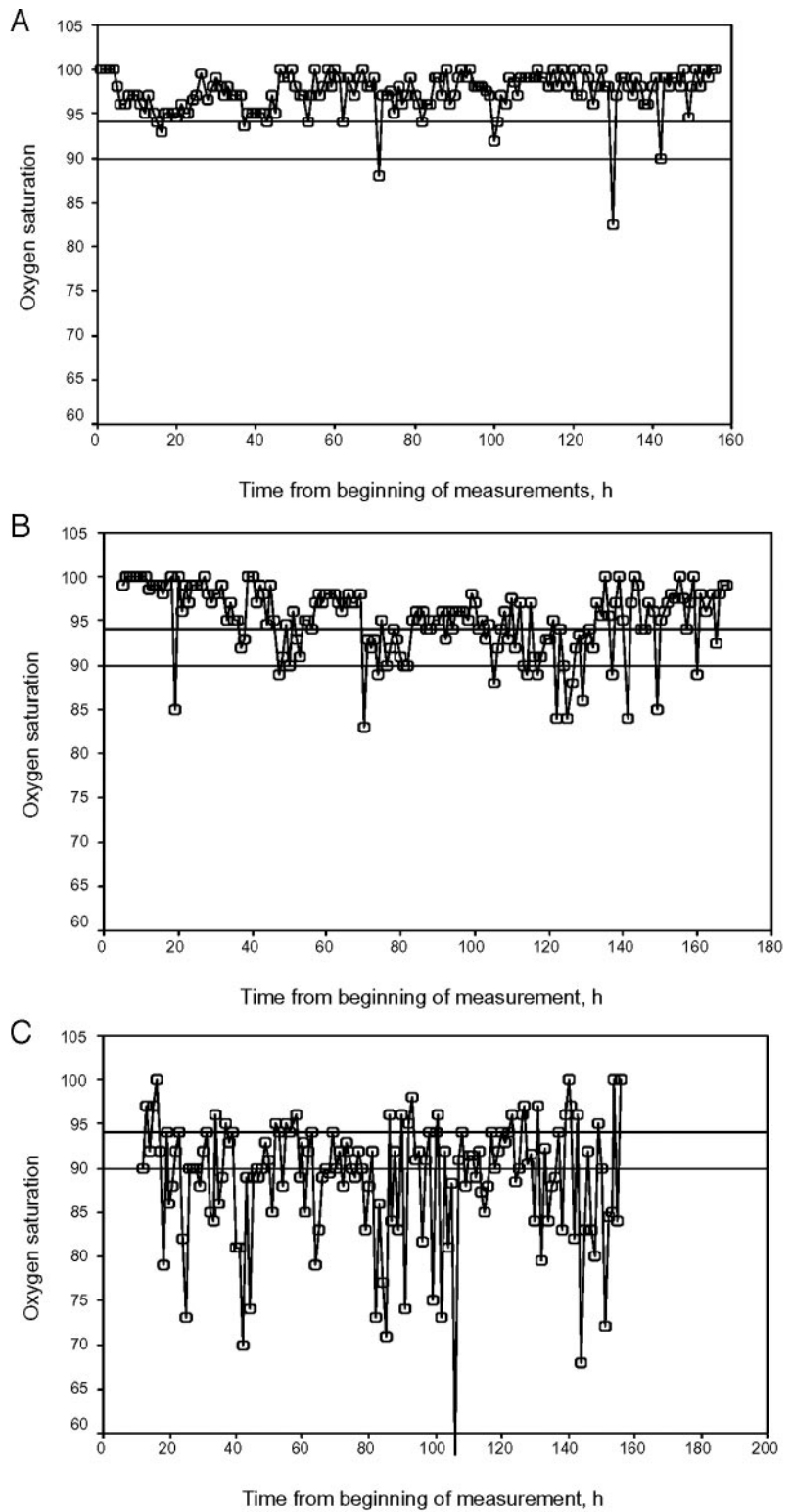


FIGURE 2
 Individual patients before and after implementation of oxygen saturation targeting. A, Average patient at <1500 g before implementation of oxygen saturation targeting. B, Individual patient data after implementation of oxygen saturation targeting. Oxygen targeting helped to bring this infant into the goal saturation range. C, Individual patient after implementation of oxygen saturation targeting. Bringing this infant into the goal range precipitated frequent desaturations.

protocol. A written survey may have allowed physicians to respond in writing independently to the proposed saturation and alarm ranges. Although consensus-building requires a greater investment of time in the planning stages, a rigorous consensus approach may result in clin-

ical practice guidelines that are better supported, as occurred in this unit's development of a standard approach to nasal cannula management.¹⁶

Detailed tracking of the change in oxygen saturations has been paramount to the success of this project. The

SpO₂ database for each patient was developed using the nursery's Quantitative Sentinel charting system. The oxygen saturation value from the beginning of each hour automatically downloaded from the monitor to the Quantitative Sentinel database and was verified by the bedside nurse. Although nursing verification of the number does not completely eliminate the potential of reporting bias, the nursing staff was more likely to verify an automatically downloaded but correct SpO₂ that was outside the target range than to enter manually a SpO₂ value that was outside the range.

Some caregivers expressed concern that 24 daily data points would not reflect accurately the saturations of any particular infant. Given that an infant is no more likely to be outside the target SpO₂ range or alarm limit range at the top of the hour than at any other minute of the hour, hourly data collection captured the overall trend for each infant. The ongoing monitoring of this data allowed targeted education throughout the process and facilitated evaluation of adherence to the protocol.

Approximately 1 month after the initiation of the protocol, the nursing staff were surveyed again to ascertain understanding of the goals of the project. The majority of nursing staff believed that the saturation protocol improved the care of VLBW infants. Resistance to the protocol was encountered when infants had wide fluctuations of SpO₂ despite careful adherence to the protocol. Although the perception was that these infants spent the majority of time outside the alarm limits, the data showed otherwise (Figs 1 and 2). The ongoing data collection allowed for presentation of percentage of time in the target range and showed improvements.

The protocol allowed physicians to modify the oxygen saturation target range and alarm limits. The upper alarm limit occasionally was increased to 98% for infants who desaturated quickly on reaching a certain threshold of 88% to 92%. These mostly were extremely low birth weight infants. Physicians were encouraged to return alarm limits to the advised range within the protocol when infant stability allowed. For a brief time, the exception of raising alarm limits for particularly fragile infants became generalized quickly in response to frequent alarms for high saturations. Close monitoring of the data allowed for quick identification and interruption of this trend.

The majority of protocol education targeted nursing and respiratory therapy staff because they provide most of the care for VLBW infants. The committee actively solicited feedback from caregivers in person in addition to that received by e-mail. In response, the committee made a concerted effort to provide timely answers to staff questions regarding implementation of the protocol as illustrated in Appendix 2. In retrospect, more education could have been provided to physicians and nurse practitioners. By not obtaining consensus from all phy-

sicians in the development of the protocol, a lack of commitment from some made the implementation of the protocol more difficult for the nursing staff and respiratory therapists. The committee overestimated the commitment to the SpO₂ targeting protocol by nurse practitioners and fellows. Because fellows and nurse practitioners are the usual first-line responders to questions regarding the management of VLBW infants, their lack of clear understanding and commitment to the protocol resulted in confusion and conflicting recommendations to bedside nurses.

Review of the data revealed that often infants who received supplemental oxygen via nasal cannula were more difficult to maintain within the target range than those who were on continuous positive airway pressure or endotracheal mechanical ventilation. This observation prompted the development of a nasal cannula protocol to provide consistent directions for use of and weaning from this form of supplemental oxygen.¹⁶ The success of any QI project depends on the commitment of both the committee that is developing and overseeing the project and all of caregivers who apply the project. To facilitate success, clinical leaders need to demonstrate support for the project, and caregivers must understand the rationale for the project and be equipped to enact the proposed change.

APPENDIX 1: OXYGEN SATURATION TARGETING PROTOCOL—BREATHSAVERS O₂ SATURATION GUIDELINES

Oxygen is a drug. It could be a very dangerous medicine with potentially significant adverse effects in VLBW preterm infants. Avoiding hypoxia is important, but prolonged hyperoxia can lead to oxidative stress and injury. There is no evidence that VLBW infants need to be managed with an FIO₂ that leads to SpO₂ of 95% to 100%, and these levels are potentially harmful. In addition, repeated episodes of alternating hyperoxia/hypoxia can promote significant alterations in vascular tone in immature infants. By avoiding these episodes, risks to the developing vascular bed in various organ systems could be minimized.

Why implement the Breathsavers O₂ saturation guidelines in our NICU?

- To lower the incidence of chronic lung disease and possibly lower the incidence of ROP

Which patients are covered by the Breathsavers O₂ saturation guidelines?

- Patients who are in the NICU and have birth weights <1500 g and are on supplemental O₂ unless specifically ordered differently by the doctor/neonatal nurse practitioner (NNP).

What are the Breathsavers O₂ saturation guidelines?

- Attempt to maintain O₂ saturations at 90% to 94% for all patients who have birth weights <1500 g and are on supplemental O₂ unless specifically ordered differently by the MD/NNP (eg, cardiac patient, at risk for persistent pulmonary hypertension [PPHN]).

- Wean oxygen actively in increments of 1% to 3% to maintain target O₂ saturations of 90% to 94% (or ordered target saturation).

1. Avoid exaggerated decreases in F_{IO₂} that could subsequently lead to hypoxia

2. Change F_{IO₂} only in small increments

- Set saturation monitor alarm limits at

1. Low 85 and high 96 for all patients who have birth weights <1500 g and are on supplemental O₂

2. Low 85 and high 103 for patients who are on room air

3. As specifically ordered by the doctor/NNP if other clinical indications (eg, cardiac patients, at risk for PPHN)

- Do not change F_{IO₂} frequently up and down to try to maintain target O₂ saturations; this can produce dangerous and risky “ups and downs” in infant’s oxygen levels. Change F_{IO₂} only in small increments.

- Every increase in F_{IO₂} requires careful assessment of infant and monitor and documentation.

1. Increase % F_{IO₂} only in increments of 1 to 3 except before procedures or with significant desaturation.

2. Do not keep increasing F_{IO₂} without notifying MD/NNP; changes in respiratory parameters may be necessary.

3. Registered nurse (RN)/respiratory therapist (RT) to remain at bedside until return to baseline and saturations have stabilized.

4. No infant should be left as “stable” if the condition has required an increase of >3% to 5% F_{IO₂}.

- Inability to maintain O₂ saturations of 90% to 94% requires discussion among team members: RN, RT, resident/NNP, and attending/fellow.

How do I implement the Breathsavers O₂ saturation guidelines?

- Change F_{IO₂} only in small increments.

1. Routinely increase or decrease F_{IO₂} in increments of 1 to 3

- a. Exception: infant has a history of desaturations with handling and procedures; increase F_{IO₂} 5% to 10% before handling/procedures.

- b. Exception: for significant desaturation (persistent Sp_{O₂} <70%) increase the F_{IO₂} to double the baseline to bring the Sp_{O₂} up quickly to 85%. Once Sp_{O₂} ≥85%, wean F_{IO₂} aggressively to within 3% of baseline.

2. Avoid exaggerated changes in F_{IO₂} (up or down), but avoid prolonged hypoxia

- a. Small incremental changes in % F_{IO₂} probably are safer than large changes (eg, frequent “tweaking” between 40% and 50% is better than periodic changes between 30% and 100%).

- b. Exception: aggressively return F_{IO₂} back to baseline after handling/procedures or significant desaturation spell.

- Response to Sp_{O₂} alarms

1. High alarms

- a. Silence and observe.

- b. At 3 minutes (when alarm sounds again), silence and observe. If saturations are not returning to baseline, then decrease F_{IO₂} by increments of 1% to 3%.

- c. Every 3 minutes, silence and observe. If saturations remain high, then continue to decrease F_{IO₂} by increments of 1% to 3%.

2. Low alarms

- a. Silence and observe

- b. Evaluate the monitor

- (1) Wave form and heart rate: is the saturation reading accurate?

- c. Evaluate the patient

- (1) Is the airway patent?

- (2) Is suctioning needed?

- (3) Is repositioning needed?

- (4) Is endotracheal tube positioned correctly?

- d. Moderate desaturation spells (Sp_{O₂} >70%)

- (1) At 3 minutes, if saturation is not increasing, then increase F_{IO₂} by increments of 1 to 3.

- (2) Every 3 minutes, if saturation is not increasing, then increase F_{IO₂} by increments of 1% to 3%.

- (3) Call doctor/NNP if persistent F_{IO₂} needs of >10% are required to maintain target saturations; changes in respiratory parameters may be needed rather than F_{IO₂}.

- e. Significant desaturation spells (Sp_{O₂} <70%)

- (1) At 3 minutes, if saturation is not increasing, then increase the F_{IO₂} to double the baseline to bring the Sp_{O₂} up quickly to 85%.

- (2) Once Sp_{O₂} ≥85%, aggressively wean F_{IO₂} to within 3% of baseline.

- (3) Call doctor/NNP if persistent F_{IO₂} needs of >10% are required to maintain target saturations; Changes in respiratory parameters may be needed rather than F_{IO₂}.

3. Multiple high and low alarms

- a. Silence and observe.

- b. Evaluate the monitor and the patient as above.

- c. Patiently watch whether the saturations will return to target range without changing the F_{IO₂}.

- d. Contact the resident/NNP/fellow/attending to discuss

- e. Consider

- (1) Personalizing the saturation alarm limits
- (2) Changes in ventilatory parameters
- (3) Nasal continuous positive airway pressure instead of nasal cannula
- (4) Hood F_{iO_2} instead of nasal cannula
- (5) Changes in nasal cannula flow
- (6) Medications (eg, albuterol, caffeine, diuretics, blood)

APPENDIX 2: FAQS FOR THE NICU BREATHSAVERS O_2 SATURATION PROTOCOL

FAQ 1: I am taking care of a “twitty” infant. I am chasing his/her saturations up and down because the monitor is alarming all the time either high or low. What should I do?

- These infants are very frustrating; evaluate the infant and the monitor for accuracy.
- Patiently watch the infant to see whether he or she will recover without changing the F_{iO_2} .
- Contact the NNP/fellow/resident, and discuss with team (doctor/NNP/RN/RT); do not stay frustrated alone.

1. May need to consider increasing high saturation alarm limit as needed to keep in target saturation range the majority of the time.

2. May need other changes: nasal continuous positive airway pressure, nasal cannula flow, ventilator parameters, medications (eg, albuterol, caffeine, blood).

3. Silence the alarms while watching the infant. Okay to decrease the decibel level of the alarms to minimize the effects to others on the pod while observing the infant.

FAQ 2: I am taking care of a near-term infant (35–38 weeks); he/she may be at risk for PPHN. Should I be following the new O_2 saturation guidelines with this infant?

- Probably not! The protocol applies to infants with birth weights <1500 g.
- Discuss with the doctor/NNP; many near-term and term infants who are on ventilation with respiratory distress/pneumonia/sepsis are at severe risk for PPHN in the first days of life.
- In these cases, the risk for PPHN may outweigh the risk for oxygen toxicity and he or she may need to be managed with higher saturations and P_{o_2} levels.

FAQ 3: My infant has a history of desaturations with handling. What should I do with procedures (suctioning, starting an intravenous line, repositioning, or heel sticks)?

- It is okay to preoxygenate. Turn up the percentage of F_{iO_2} by 5 to 10 immediately before procedure.

- Turn O_2 down as soon as possible.

FAQ 4: Should I routinely hand-ventilate my infant (eg, before suctioning or to do an assessment)?

- Avoid large changes in P_{o_2} and saturations. Use options other than hand ventilation.
 1. Provide manual breaths from the vent.
 2. Preoxygenate (increase O_2 5% to 10%, then turn back down as soon as possible).
 3. Only hand-ventilate when essential.

FAQ 5: Why is the “goal” O_2 saturation range different from the O_2 saturation monitor alarm settings?

- It is impossible to achieve the goal all the time—we recognize this! However, the target O_2 saturation range should be the ultimate goal.
- The monitor alarm settings are wider than the goal range with the reality that by responding to the alarms, the infant will be in the goal range for an acceptable percentage of the time.
- It is okay for the saturations to be lower than the goal but within the monitor alarm range for a period of time. However, if the infant’s saturations consistently are outside the goal saturation range but within the monitor alarm ranges, then changes need to be made.

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