IMPROVING PRETERM INFANTS' OXYGEN SATURATION TARGET TIME: A QUALITY IMPROVEMENT INITIATIVE

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Abstract

Background: Preterm infants born before 32 weeks' gestation are at especially high risk of the harmful effects of supplemental oxygen received after birth. A fine balance exists between provision of too much or too little oxygen support. The Neonatal Oxygenation Prospective Meta-analysis (NeOProM) Collaboration recommends oxygen saturation targets of 90-95%. Oxygen saturation histograms are a non-invasive way to monitor oxygen saturation data for preterm infants receiving supplemental oxygen in the neonatal intensive care unit (NICU) and can facilitate compliance with recommended oxygen saturation targets.

Purpose: The purpose of this quality improvement initiative was to 1) educate bedside staff in a level IV NICU about oxygen saturation targets based on recommendations from the Committee on Fetus and Newborn and NeOProM, and 2) to increase the amount of time preterm infants spend within their ordered oxygen saturation target.

Methods: Five total cycles of education and data collection were performed. Data collection involved evaluating histograms for time preterm infants less than 32 weeks' gestation spent below (<90%), within (90% - 95%), and above (>95%) their ordered oxygen saturation target. Education sessions reinforced the current unit protocol of oxygen saturation targeting of 90-95% for preterm infants less than 32 weeks' gestation.

Results: At baseline, preterm infants were within their target oxygen saturation range 32% of a 24-hour period, or approximately 7.7 hours. This time increased to 45% of a 24-hour period (approximately 10.8 hours) during cycle 3 but returned to baseline at 32% of a 24-hour period during cycle 4. Overall, preterm infants were within their target oxygen saturation range 37% of a 24-hour period, which is a 5% increase over baseline, equivalent to an additional 1.2 hours spent within target range.

Recommendations and Conclusions: Overall, the project was successful in increasing the amount of time spent within the range by an additional 1.2 hours per day, on average. Oxygen saturation histograms are helpful tools for assessing compliance with narrow oxygen saturation targets. Ongoing evaluation of oxygen saturation histograms is recommended for continued compliance with narrow oxygen saturation targets and overall improvement in provision of appropriate supplemental oxygen. Effects of education may not be retained over time. More targeted education of newer nursing and respiratory therapy staff may be warranted. Routine audits of oxygen saturation monitor alarm settings is another tool that could be used to ensure appropriate targeting of oxygen saturations for preterm infants.

Keywords: oxygen saturation; oxygen saturation targeting; oxygen saturation goals; oxygen saturation limits; oxygen saturation histograms; oxygen histogram monitoring; neonatal intensive care unit; preterm infants; retinopathy of prematurity

Background and Significance

Supplemental oxygen is one of the most common therapies provided to preterm infants following birth to assist the infant in transitioning from the hypoxic intrauterine environment to the oxygen rich extrauterine environment (Newnam, 2014; Kayton et al., 2018). However, provision of too much or too little supplemental oxygen can lead to increased complications, such as an increased risk for retinopathy of prematurity (ROP), necrotizing enterocolitis (NEC), bronchopulmonary dysplasia (BPD), intraventricular hemorrhage (IVH), and even death (Newnam, 2014; Kayton et al., 2018). Pulse oximetry has become the gold standard for monitoring oxygen saturation levels due to its widespread availability in neonatal care settings. Numerous studies have been done to determine the most appropriate pulse oximetry parameters for preterm infants, and a fine balance exists between provision of too much or too little oxygen support (Kayton et al., 2018). Supplemental oxygen levels that are too high lead to hyperoxia, which can lead to complications such as ROP; supplemental oxygen levels that are too low lead to hypoxia, which can lead to complications such as NEC (Schmidt & Kirpalani, 2022).

Targeting narrow oxygen saturation levels has proved challenging for neonatal bedside staff (including respiratory therapists and nurses). This is related to inadequate or understaffing, lack of knowledge of institutional oxygen saturation targets as the number of travelling nurses rises, and alarm fatigue among bedside nurses (Ali et al., 2021). Observations show that bedside nurses are more tolerant of hyperoxia and respond less diligently to high oxygen saturation alarms than to low oxygen saturation alarms (Schmidt & Kirpalani, 2022). This results in infants who receive supplemental oxygen spending time outside of their oxygen saturation target range.

Oxygen saturation histograms are a non-invasive, cost-effective way to provide objective data for monitoring oxygenation trends of preterm infants. Monitoring these trends can increase compliance with oxygen saturation targets (Ali et al., 2021; Gentle et al., 2020). Through daily evaluation of oxygen saturation histograms by providers, bedside nurses, and respiratory therapists, Gentle et al. (2020) were able to increase the amount of time spent within target range from 48.7% to 57.6%, equaling an approximate increase in time spent within range of an additional 2.5 days during a 30-day month.

Bedside staff in the neonatal intensive care unit (NICU) are responsible for the titration of the fraction of inspired oxygen (fiO2) for infants who are receiving supplemental oxygen. However, it is sometimes difficult to maintain infants within prescribed oxygen saturation targets due to immaturity of the lungs. When infants' saturations are outside of their prescribed oxygen saturation targets, monitors alarm to notify bedside nurses (alarm limits should be set as 90% for lower limits and 95% for upper limits according to this NICU's protocol). The frequency of these alarms can lead to alarm fatigue among staff. Alarm fatigue may contribute to more tolerance for hyperoxia than hypoxia in preterm infants because it is assumed that hyperoxia is safer than hypoxia. However, Sola et al. (2014) explain that hyperoxia is caused by healthcare providers, as it is not a natural occurrence, and the human body is unable to compensate for increased oxygen states.

In utero, gas exchange occurs through the placenta, nullifying the need for gas exchange in fetal lungs (Kayton et al., 2018). After birth, there is increased blood flow to the lungs in response to the vasodilation caused by oxygen as air enters the lungs (Kayton et al., 2018). However, preterm birth exposes the premature pulmonary circulation to oxygen before being able to effectively manage gas exchange (Kayton et al., 2018). This leads to the need for respiratory support and supplemental oxygen in approximately 1 in 10 infants following delivery (Kayton et al., 2018). In recent years 100% oxygen was universally used for resuscitation of infants because of the known harmful effects of hypoxia and the known helpful effects of oxygen on pulmonary vascularization (Kayton et al., 2018; Ali et al., 2021). However, studies on infant resuscitation have found no benefits associated with high oxygen exposure at birth when compared to lower oxygen levels (21-30%) (Kayton et al., 2018). Current recommendations from the Neonatal Resuscitation Program of the American Heart Association include using 21% oxygen for initial resuscitation of infants 35 weeks' gestation or older, and 21-30% oxygen for infants born younger than 35 weeks' gestation (Kayton et al., 2018).

Neonatal clinicians have been monitoring oxygenation through non-invasive measures for years. Pulse oximeters are the most appropriate bedside measures to estimate arterial oxygen saturation and guide oxygen administration for preterm infants (Schmidt & Kirpalani, 2022; Kayton et al., 2018; Ali et al., 2021). Following birth, oxygen saturation levels gradually rise to normal levels (93% or greater) over the first 10 minutes of life as the infant's circulation transitions to extrauterine life (Kayton et al., 2018). Right upper extremity placement of the pulse oximeter probe provides the most accurate estimation of oxygen delivery to the brain during neonatal resuscitation; the wrist, palm, and foot are common sites for application of pulse oximeter probes outside of the delivery room (Ali et al., 2021). While pulse oximeters are advantageous due to widespread availability, non-invasive monitoring, and quick detection of fluctuations in oxygen levels, there are also some technical and physiologic limitations to pulse oximetry monitoring (Ali et al., 2021). Motion artifact and electromagnetic interference may affect the accuracy of measurements, as well as physiologic changes such as hypotension, hypoperfusion, severe anemia, and hemoglobinopathies (Ali et al., 2021).

Numerous studies have been conducted to determine the most appropriate oxygen saturation targets outside of the delivery room. The Neonatal Oxygenation Prospective Meta-analysis (NeOProM) Collaboration utilized the results of five randomized controlled trials to determine appropriate oxygen saturation targets for preterm infants. In these trials, infants were randomly assigned to oxygen saturation targets of 85-89% or 91-95%, and the primary outcome composite of death or disability at 18-24 months corrected age was not significantly different between these two target groups (Schmidt & Kirpalani, 2022; Ali et al., 2021). The higher oxygen saturation targets did show decreased risk of death and severe NEC, but also an increased risk of ROP requiring treatment (Schmidt & Kirpalani, 2022). Guidelines following NeOProM recommend target oxygen saturation ranges of 90-94% or 91-95% for all infants born prematurely (Schmidt & Kirpalani, 2022). The goal of oxygen saturation targeting is to prevent hypoxia while avoiding hyperoxia as much as possible, and target levels should be individualized for each patient (Kayton et al., 2018).

Purpose

The purpose of this quality improvement project was:

- To educate bedside staff in a level IV NICU about oxygen saturation targets based on the unit's current policy.
- To increase the amount of time preterm infants spend within their ordered oxygen saturation target.

This quality improvement initiative sought to answer the following question: When assessed by neonatal bedside nurses and respiratory therapists, do oxygen saturation histograms increase the amount of time preterm infants spend within their oxygen saturation target? This target range is 90-95% based on the current policy in a level IV NICU.

Review of Current Evidence

In order to support the NICU's current oxygen saturation protocol, a review of current evidence was performed. Search terms included supplemental oxygen, supplemental oxygen in preterm infants, oxygen saturations, oxygen saturation in preterm infants, retinopathy of prematurity, oxygen saturation histograms, and oxygen histogram monitoring. Research articles were obtained using PubMed and Google Scholar, and 15 articles were reviewed.

Supplemental oxygen therapy is required at birth for approximately 10% of all infants, and even more so for infants born preterm (Kayton et al., 2018). Despite its commonality, there is still debate about optimal oxygen saturation targets for preterm infants. Pulse oximetry has become the gold standard form of non-invasive monitoring of oxygenation due to its widespread availability (Ali et al., 2021; Schmidt & Kirpalani, 2022). Pulse oximeters estimate the arterial oxygen saturation, for which 93% or greater is normal for healthy newborns (Kayton et al., 2018). The most common sites for pulse oximeter probe placement are the wrist, palm, and foot; right upper extremity probe placement provides the best estimate of oxygenation to the infant's brain and is the recommended placement site during resuscitation at delivery (Ali et al., 2021). In utero, gas exchange occurs via the placenta with a relatively low oxygen saturation; at birth infants transition to extrauterine circulation and oxygen saturations gradually increase to normal values over the first 10 minutes of life (Kayton et al., 2018). Many studies have been conducted to determine the safest oxygen saturation parameters for preterm infants, including the Surfactant, Positive Pressure, and Pulse Oximetry Randomized Trial (SUPPORT), three Benefits of Oxygen Saturation Targeting (BOOST, BOOST II) studies, and Canadian Oxygen Trial (COT), and the results of these trials were combined by the Neonatal Oxygen Prospective Meta-analysis (NeOProM) Collaborative (Kayton et al., 2018). These studies demonstrated risks and benefits of different oxygen saturation targets at different ages.

Because of the frequency of use at delivery, supplemental oxygen therapy is considered the most common therapeutic agent for neonatal care (Kayton et al., 2018). However, ongoing debate exists about the most appropriate oxygen saturation for preterm infants; too much supplemental oxygen increases the risk for severe ROP while too little supplemental oxygen increases the risk for NEC and death (Kayton et al., 2018). In utero, gas exchange occurs via the placenta while the fetal lungs grow and mature. When infants are born preterm, they are exposed to oxygen before the lungs have matured enough to manage this oxygen exposure, leaving the preterm infant at risk for hypoxia and hyperoxia (Kayton et al., 2018). Hypoxia is the result of an oxygen supply and demand mismatch. There is a great demand for oxygen with a low supply which leads to low oxygen saturations. Hyperoxia results from an increased supply of oxygen that the body does not necessarily need, leading to the formation of toxic reactive oxygen species (Kayton et al., 2018). Hypoxia leads to cell death and ischemia, which increases the risk for NEC and mortality in preterm infants (Newnam, 2014). While supplemental oxygen is used to reverse hypoxia in the preterm infant, too much oxygen can lead to increased oxidative stress due to the infant's limited antioxidant defense mechanisms (Kayton et al., 2018). This oxidative stress can damage brain, lung, and eye tissue (Newnam, 2014). In the past, 100% oxygen was used universally for neonatal resuscitation, but recent research has determined that overexposure to oxygen increases the risk of oxidative stress (Kayton et al., 2018). The American Heart Association currently recommends that infants born at 35 weeks' gestation or older be resuscitated with 21% oxygen, and infants born younger than 35 weeks' gestation can be resuscitated with 21-30% oxygen based on recent randomized studies demonstrating a decreased risk of mortality when resuscitated with 21% oxygen compared with 100% oxygen (Kayton et al., 2018).

Healthy infants born at term gestation can take up to 10 minutes after birth before reaching normal oxygen saturation levels of 93% (Kayton et al., 2018). Following the initial resuscitation period, it remains unclear what oxygen saturation targets are appropriate for preterm infants. The NeOProM Collaboration suggested that lower oxygen saturation targets lead to higher mortality rates and higher risk of NEC while higher oxygen saturation targets (91-95%) are safer (Kayton et al., 2018). In the NeOProM Collaboration, there was no significant difference in the primary composite outcome of death or major disability at the corrected age of 18 to 24 months between lower oxygen saturation target ranges of 85-89% and higher oxygen saturation target ranges of 91-95% (Askie et al., 2018). The collaboration did however demonstrate a significant difference in death and severe NEC in the lower oxygen saturation group (19.9% vs. 17.1% and 9.2% vs. 6.9% respectively) (Askie et al., 2018). In the higher oxygen saturation target group, 4% more infants required treatment for ROP versus the lower oxygen saturation group (Askie et al., 2018). Maintaining narrow oxygen saturation targets has proved to be challenging and must be individualized for each patient, with the goal of preventing hypoxia and hyperoxia.

Following the NeOProM Collaboration, current recommendations for target oxygen saturation ranges are 91-95% for preterm infants, however these infants are outside of this target range approximately 50% of the time (Schmidt and Kirpalani, 2022; Ali et al., 2021). A study by Ketko et al. (2015) found that narrow oxygen saturation targets increased alarms by a total of 27 alarms per patient per day. Compliance with narrow oxygen saturation targets is often low due to inadequate staff to patient ratios and fatigue related to long work hours (Schmidt and Kirpalani, 2022). Alarm fatigue may also contribute to decreased compliance with oxygen saturation targets, and high false alarm rates increase the risk of fatigue (Ali et al., 2021; Stefanescu et al., 2016). Some studies suggest that bedside nurses are more responsive to hypoxia and more complacent with hyperoxia, however studies also suggest that adequate training, unit-specific guidelines, and regular assessments of oxygen saturation histograms may improve nursing compliance with oxygen saturation targets, by as much as 7.2% of the time over baseline (Schmidt and Kirpalani, 2022; Ketko at al., 2015). Not only does monitoring histograms increase the amount of time infants spend within their target range, the number of alarms per monitored patient can be decreased (Ketko et al., 2015).

Studies of the effect of oxygenation on ROP development began in the 1990s (Higgins, 2019). The Supplemental Therapy with Oxygen to Prevent Retinopathy of Prematurity (STOP-ROP) trial sought to determine if higher oxygen saturation levels would reduce the rate of progression of ROP by randomizing infants to target oxygen saturation groups of 96-99% versus 89-94%; there was no reduction of progression of ROP noted in the higher oxygen saturation group (Higgins, 2019). SUPPORT and BOOST II noted a lower rate of ROP development in lower oxygen saturation target groups, but also a higher rate of death in this lower group (Higgins, 2019). COT noted no difference in the rate of ROP between lower and higher oxygen saturation target groups but did see a slightly higher rate of death or survival with disability in the lower oxygen saturation target group (Higgins, 2019). The final recommendations from these studies do not support targeting oxygen saturations lower than 90%, but rather targeting an oxygen saturation range of 90-95% reduces the incidence of comorbidities (Newnam, 2014).

Bedside staff complacency with hyperoxia may be contributing to an upward trend in the development of ROP (Choo et al., 2021). Aly et al. (2022) noted an increase in the incidence of

ROP from 0.5% in 2008 to 3.6% in 2017. This is concerning because ROP is the second leading cause of childhood blindness in the United States (Aly et al., 2022). One study evaluated the trend for ROP over a 14-year period while implementing a change to more narrow and higher oxygen saturation targets and noted no difference in the incidence of ROP between higher and lower oxygen saturation target group, although the higher oxygen saturation target group did show more progression of ROP (Choo et al., 2021). While there was an increase in progression of ROP in the higher target group, the number of ROP cases requiring treatment was approximately 50% lower (Choo et al., 2021). These study results demonstrate that although higher oxygen saturation target groups may lead to increased progression of ROP, treatment is required less frequently.

Suggestions have been made by Schmidt and Kirpalani (2022), Newnam (2014), and Ali et al. (2020) to improve bedside nurses' compliance with narrow oxygen saturation targets. Suggestions include adequate staff to patient ratios, sensible workhours, explicit protocols and training, and review of oxygen saturation histograms. Implementing review of bedside oxygen saturation histograms brings awareness of trends in infants' oxygen saturations to bedside nurses and respiratory therapists. When evaluation of oxygen saturation histograms by bedside nurses was implemented, Srivatsa et al. (2021) noted an upward trend in the amount of time infants spent within their prescribed target range while also demonstrating a significant downward trend in mortality, ROP, and BPD. Likely one of the most effective strategies to improve compliance is nursing education regarding negative effects of hypoxia and hyperoxia, as well as unit-specific guidelines for oxygen saturation targets and titrations (Newnam, 2014).

Current standard of care for compliance with targeted oxygen saturations is manual titration of supplemental oxygen by bedside staff (Schmidt and Kirpalani, 2022). Technology is currently being studied for automated oxygen control systems and although these systems may decrease the workload for bedside staff, similar clinical outcomes are demonstrated when compared to manual titration (Schmidt and Kirpalani, 2022).

Studies analyzed in the NeOProM Collaboration randomized preterm infants to low oxygen saturation targets (85-89%) and high oxygen saturation targets (91-95%), and evaluated outcomes of death, NEC, bronchopulmonary dysplasia (BPD), and ROP (Ali et al., 2021). An increase in the rates of NEC and mortality were noted when lower oxygen saturations were targeted (85-89%) when compared to higher oxygen saturation targets (91-95%) (Ali et al., 2021). Based on these findings, most NICUs target oxygen saturations 91-95% for preterm infants. Bedside staff tend to tolerate hyperoxia more often than hypoxia, studies show, however hypoxia increases the risk and severity of ROP and neurodevelopmental impairment (Ali et al., 2021).

Oxygen saturation histograms provide a visual representation of the amount of time infants spend at specified oxygen saturations (Gentle et al., 2020). By implementing regular evaluation of oxygen saturation histograms by the care team, the amount of time preterm infants spent within their target range improved by 8.9% over the 30-day study period, equaling approximately 2.5 additional days spent within target range (Gentle et al., 2020). Sivanandan et al. (2018) also noted a 10.6% improvement in the amount of time preterm infants spent within a target oxygen saturation range when oxygen saturation histograms were reviewed by bedside nurses. This improvement in time spent within range decreases the number of times preterm infants experience hypoxia or hyperoxia, therefore potentially reducing the adverse effects associated with oxidative states.

Conceptual Model

The Awareness-to-Adherence model described by Pathman et al. (1996) states that, first, care providers must be aware of a guideline to comply with it. Then providers must intellectually agree with the guideline before deciding to adopt it into their care. Following agreement and adoption, care providers then adhere to the guideline at appropriate times. In the awareness-to-adherence model, failure can occur at any of the four steps, resulting in non-compliance with the guideline (Pathman et al., 1996). Applying this model to unit-specific guidelines can help with identification of factors that affect failure and at which steps failure occurs. This model assists in identifying opportunities for improvement with compliance with ordered oxygen saturation targets in the NICU.

Diffusion of education and guidelines occurred in the awareness stage (Jhyla et al., 2017). Awareness was increased through education and enhanced communication. In this project, awareness was promoted through education of bedside staff (nurses and respiratory therapists) about the current oxygen saturation targeting policy in the NICU via informal education sessions within the NICU, including face-to-face interactions at the bedside during daily rounds and at nursing and respiratory workstations. Dissemination of the protocol occurred during the agreement stage, during which the risks and benefits of oxygen saturation targeting was communicated to bedside staff (Jhyla et al., 2017). The adoption stage involved implementing the oxygen saturation targeting policy into daily practice. I sought to improve adherence to the current oxygen saturation targeting policy in the NICU by incorporating evaluation of oxygen saturation histograms into daily patient rounds with the multidisciplinary team, including providers, bedside nurses, and respiratory therapists among others. According to Jhyla et al. (2017), adherence occurs for only about one third of new guidelines. Successful adoption and adherence require buy-in by individual care providers as well as unit leaders and requires a plan for continuous evaluation of outcomes (Jhyla et al., 2017). I had planned to audit printing of histograms by bedside nurses at the end of their shifts for preterm infants born at less than 32 weeks' gestation.

Translational Framework

Six Sigma is a quality improvement process that was initiated in the business industry, by Motorola specifically, to improve overall quality and customer satisfaction using the DMAIC process (Niñerola, Sánchez-Rebull, & Hernández-Lara, 2020). The DMAIC acronym stands for Define (define the problem to be improved); Measure (develop a data collection plan and gather data); Analyze (use statistical methods to analyze the gathered data); Improve (develop implementation and monitoring plans for the solution); and Control (sustain the improvements achieved during the improvement process) (McKay, 2017). The Six Sigma model seeks to improve outcomes by minimizing variation and provides an outline for performing quality improvement processes (Polit and Beck, 2021).

The goal of this DNP project was to increase compliance with ordered oxygen saturation targets for infants born preterm at less than 32 weeks' gestation. The Six Sigma model provided a five-step checklist for guiding this quality improvement process, ensuring all aspects of the process were completed. The defined problem is non-compliance with ordered oxygen saturation targets for infants born preterm at less than 32 weeks' gestation. To measure compliance and non-compliance, I performed bedside monitor audits of set alarm limits, in addition to monitoring of bedside oxygen saturation histograms that provided a visual display of the percentage of time infants spent at different oxygen saturations. Percentages were used to describe the data in terms of below, within and above range. To improve compliance with ordered oxygen saturation targets, I communicated with bedside staff in the NICU the importance of adhering to the current oxygen saturation policy. For the control and sustaining step of the Six Sigma process, I engaged in frequent communication sessions with bedside staff regarding the importance of oxygen saturation targets and preventing hypoxia and hyperoxia. An additional action for sustaining compliance is incorporation of oxygen saturation histogram evaluation by providers into daily rounds. This action item is a long-term goal that has not yet been accomplished.

Methods

The oxygen targeting protocol for the Level IV NICU at a major regional children's hospital in North Carolina states that infants who are less than 32 weeks' gestation should have oxygen saturation monitor alarm limits set at 90-95% until 32 weeks' gestation is reached (Atrium Health Wake Forest Baptist, 2022). This protocol is based on recommendations from the Committee on Fetus and Newborn following recommendations from the NeOProM Collaboration. These guidelines are not routinely met and preterm infants experience hypoxia or hyperoxia. The purpose of this quality improvement project was to increase the amount of time preterm infants less than 32 weeks' gestation spend within their ordered oxygen saturation target through educating bedside nurses' and respiratory therapists' regarding the current oxygen targeting protocol and evaluation of oxygen saturation histograms. This section describes the design and implementation of this project, centered around the Six Sigma translational framework.

Design

The Centers for Medicare and Medicaid define quality improvement as a process to reduce variation in patient care and improve patient outcomes (CMS, 2021). This quality improvement project sought to increase the amount of time preterm infants spend within a safe oxygen saturation range, which also means receiving an appropriate level of supplemental oxygen support as bedside nurses and respiratory therapists titrate oxygen concentrations to maintain the oxygen saturation target.

Population

The population for this project was infants born at less than 32 weeks' gestation in a level IV NICU at a major regional children's hospital in North Carolina. When infants are admitted to the NICU, monitor settings are entered based on their gestational age. According to the oxygen targeting protocol at the project site, all infants born at less than 32 weeks' gestation who are receiving supplemental oxygen have low oxygen saturation limits set at 90% and high limits set at 95%, and alarms notify bedside nurses and respiratory therapists when infants are outside of these limits. The monitors of all infants less than 32 weeks' gestation at the time of data collection were assessed for appropriate oxygen saturation settings, and oxygen saturation histograms were obtained from these patient monitors as well. Appropriate oxygen saturation limits are essential to ensuring appropriate titration of supplemental oxygen. Preterm infants are more susceptible to injury from oxidative stress following delivery, especially those born very preterm at less than 32 weeks' gestation, including increased incidence of NEC in hypoxic states and ROP in hyperoxic states, among others (Newnam, 2014).

All bedside nurses and respiratory therapists working in the NICU are expected to be aware of the current policies, protocols, and guidelines. All bedside nurses and respiratory therapists working in the NICU were asked to participate in brief education sessions regarding the current oxygen targeting protocol.

Setting

The NICU in this major regional children's hospital in North Carolina consists of 74 individual patient rooms, five of which are designated for two infants (twins), divided into four areas called neighborhoods, allowing for a total capacity of 78 patients. Infants may be admitted directly from the labor and delivery unit, the newborn nursery, or transferred from an outlying facility, and they are admitted to rooms throughout the neighborhoods at random.

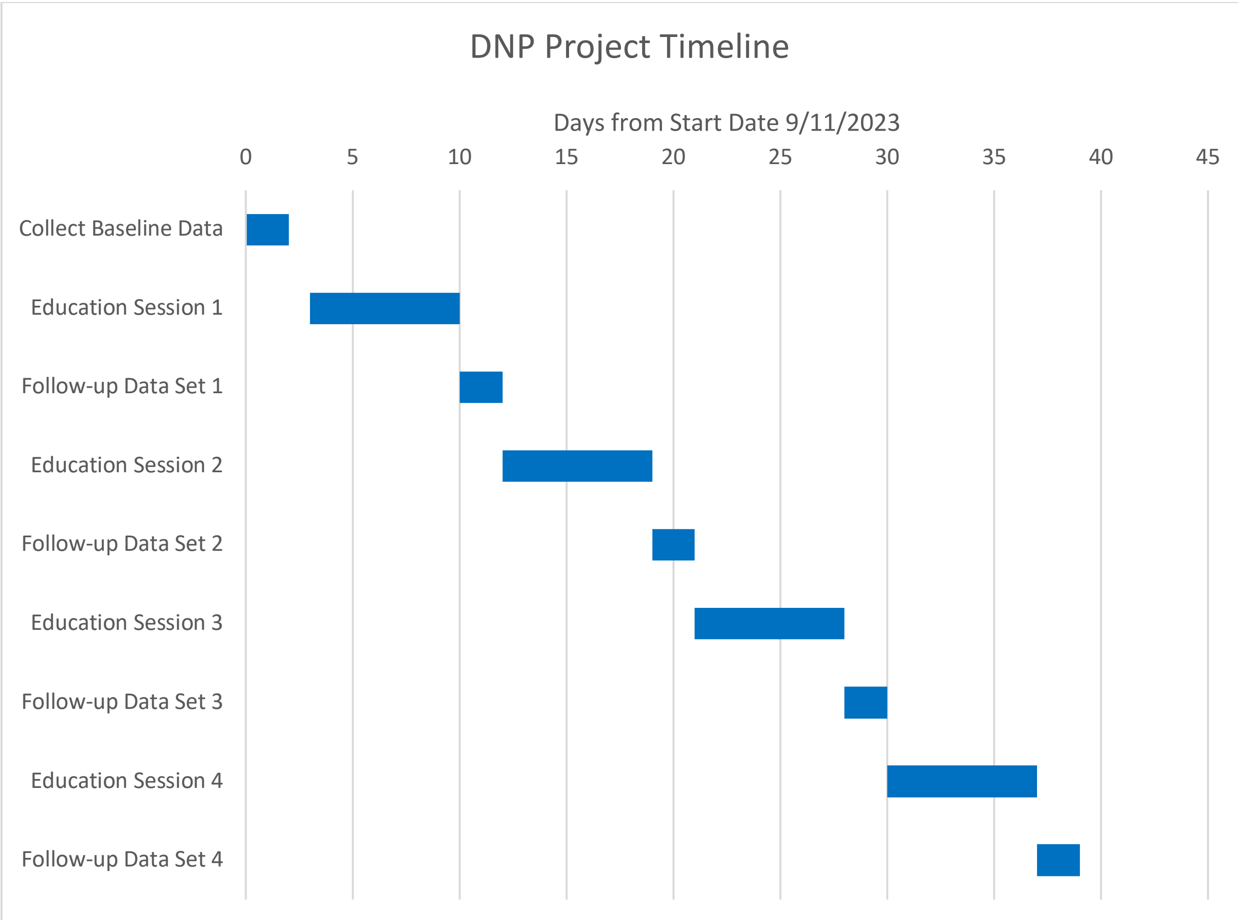
The NICU is staffed by bedside nurses, respiratory therapists, neonatal nurse practitioners, pediatric residents, neonatology fellows, and neonatologists, among additional ancillary staff. Bedside nurses and respiratory therapists are responsible for continuously monitoring infants and ensuring oxygen targeting guidelines are followed.

Project Implementation

Because bedside nurses and respiratory therapists are expected to be aware of and understand the current oxygen targeting protocol prior to beginning work in the NICU, this project focused on reinforcement of education of this protocol. I reviewed the current protocol with bedside nurses and respiratory therapists in brief informal education sessions face-to-face in bedside rounds and at various nursing workstations throughout the unit. After reviewing the protocol, bedside nurses and respiratory therapists were encouraged to ask clarifying questions. I also reviewed what oxygen saturation histograms are and how they are used to evaluate the amount of time infants spend within their target range. Oxygen saturation histograms provide a visual depiction of oxygen saturation distributions over time and help NICU care providers to trend patient data (GE Healthcare, 2022). Reviewing the benefits of oxygen saturation histograms will hopefully encourage bedside nurses and respiratory therapists to review their assigned patients' oxygen saturation histograms during their shifts to assess how well oxygen targeting is being done. See Appendix A for an example of an oxygen saturation histogram.

Instruments. Philips Intellivue monitors are the cardiorespiratory monitors used in this NICU. These monitors have built-in algorithms that trend oxygen saturation data and display it in a bar graph that illustrates the amount of time spent within a set range, usually as a percent (GE Healthcare, 2022; Sur & Paria, 2021). Due to technical difficulties, the monitors did not communicate with the printers, and I was unable to print 24-hour oxygen saturation histograms for review. However, histograms were displayed on the monitors as well as the percentages for ranges of oxygen saturations for the previous 24 hours, so this data was manually entered into an Excel worksheet (see Appendix B).

Timeline and critical milestones.



This project took place in four 1–2-week cycles, beginning September 13, 2023. Baseline data collection took place for the first two weeks (September 13-27). The first education sessions took place for two days (October 2-3). Cycle one of data collection then occurred October 3-20. The second education sessions occurred for two more days (October 23-24). Cycle two of data collection occurred October 25-31. The third education sessions occurred November 1-2. Cycle three of data collection took place November 3-7. The fourth and final education sessions occurred November 8-9. Cycle four of data collection was done November 13-17. Data analysis was performed once data collection was complete.

IRB approval. No individual data or protected health information (PHI) was collected, and all data is reported in aggregate. This project was designated as "Not Human Subjects Research" by the IRBs at the University of North Carolina Greensboro and the clinical site.

Implementation Procedure. I obtained baseline data from all preterm infants less than 32 weeks' gestation in all neighborhoods, including percentage of time spent below, within, and above target range for the previous 24 hours from oxygen saturation histograms. The NICU population is typically 30-40% preterm infants less than 32 weeks' gestation and with an average daily census of 60, it was expected to take up to two days to collect 35 histograms. However, when data collection was started, the overall patient census was lower than usual, and the number of preterm infants less than 32 weeks' gestation was less than usual as well so baseline data collection took longer than expected. After baseline data was collected, I began cycles of education and follow-up data collection by hosting brief informal education sessions with bedside nurses and respiratory therapists during daily bedside rounds and at nursing workstations throughout the unit. The education sessions lasted only a few minutes and reviewed the current oxygen targeting protocol in addition to describing oxygen saturation histograms and their use. This education was repetitive, in that I reviewed the current NICU guideline for oxygen saturation targets as well as the risks/benefits of maintaining these targets for preterm infants. These education sessions contained the same information, so it was not necessary for bedside nurses and respiratory therapists to attend more than one session. Informal education occurred multiple times a day for two days in each cycle with follow-up data collection occurring over the next several days until 32-35 histograms were obtained for each cycle of data collection. Post-intervention data, including percentage of time spent within target range over the previous 24 hours from oxygen saturation histograms, was collected during each data collection period. This project took longer than expected and lasted approximately 10 weeks.

Data analysis

Histograms displaying oxygen saturations for the previous 24 hours were evaluated from bedside monitors of infants less than 32 weeks' gestation during each data collection period until 32-35 histograms were obtained. Histograms were collected from multiple patients and multiple patient monitors From the oxygen saturation histogram, I added the percentage of time from each of the bins within the respective ranges and recorded the total percentage of time the infant spent below, within, and above the target oxygen saturation range. These data were then analyzed for range, mean, median, and standard deviation. This information is presented in graphical form using a run chart. During data collection cycles, histograms may have been collected more than once for patients, however no patient-specific data was collected so it was impossible to track which patients and how often this was occurring.

Results

Evaluate Outcomes

Baseline data was collected from September 13 to September 27, 2023, and consisted of 32 oxygen saturation histograms. At the time these 32 histograms were collected, thirteen of the infants were not receiving supplemental oxygen. This is relevant to data collection because it skews the oxygen saturation histogram to the right, meaning it will appear that infants spend more time above their target oxygen saturation range. When infants do not require supplemental oxygen, bedside nurses and respiratory therapists cannot decrease the inhaled oxygen concentration below room air (or 21% oxygen) and according to the unit protocol, high oxygen saturation limits may be set to 100% when infants are not receiving supplemental oxygen. At baseline, preterm infants were below their target oxygen saturation range on average 14% (approximately 3.4 hours) of a 24-hour period (range 0-64%; median 11%; SD 14%). Preterm infants were within their target oxygen saturation range on average 32% (approximately 7.7 hours) of a 24-hour period (range 1-61%; median 34%; SD 14%) at baseline. Preterm infants were above their target oxygen saturation range on average 54% (approximately 13 hours) of a 24-hour period (range 2-98%; median 56%; SD 24%). When baseline data collection was done, fifteen monitors had incorrect high alarm settings which potentially led to higher amount of time spent above target range. Baseline education for bedside nurses and respiratory therapists occurred September 28 to October 3, 2023.

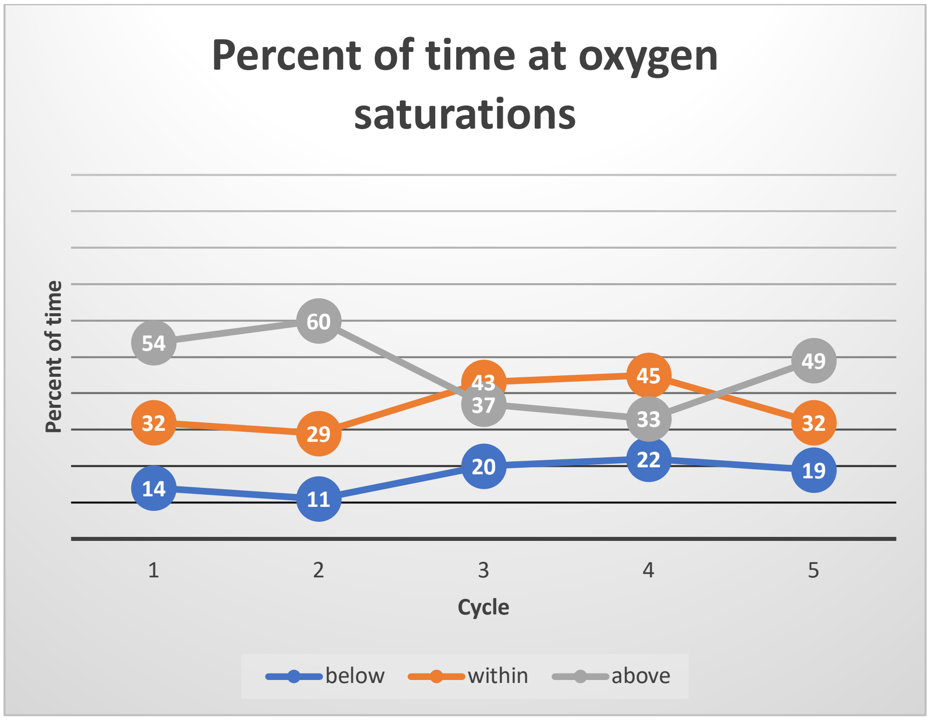
Cycle 1 of data collection occurred October 3 through October 20, 2023, and consisted of 32 oxygen saturation histograms. At the time these 32 histograms were collected, fourteen of the infants were not receiving supplemental oxygen. During cycle 1 data collection, preterm infants were below their target oxygen saturation range on average 11% (approximately 2.6 hours) of a 24-hour period (range 0-44%; median 6%; SD 14%). Preterm infants were within their target oxygen saturation range on average 29% (approximately 7 hours) of a 24-hour period (range 0-72%; median 28%; SD 23%) during cycle 1. Preterm infants were above their target oxygen saturation range on average 60% (approximately 14.4 hours) of a 24-hour period (range 8-100%; median 61%; SD 32%) during cycle 1. Education cycle 1 for bedside nurses and respiratory therapists occurred October 21 through October 24, 2023.

Cycle 2 of data collection occurred October 25 through October 31, 2023, and consisted of 35 oxygen saturation histograms. At the time these 35 histograms were collected, six of the infants were not receiving supplemental oxygen. During cycle 2 data collection, preterm infants were below their target oxygen saturation range on average 20% (approximately 4.8 hours) of a

24-hour period (range 0-42%; median 22%; SD 10%). Preterm infants were within their target oxygen saturation range on average 43% (approximately 10.3 hours) of a 24-hour period (range 6-70%; median 45%; SD 16%) during cycle 2. Preterm infants were above their target oxygen saturation range on average 37% (approximately 8.9 hours) of a 24-hour period (range 7-93%; median 33%; SD 23%) during cycle 2. Education cycle 2 for bedside nurses and respiratory therapists occurred November 1 and 2, 2023.

Cycle 3 of data collection occurred November 3 through November 7, 2023, and consisted of 34 oxygen saturation histograms. At the time these 34 histograms were collected, five of the infants were not receiving supplemental oxygen. During cycle 3 data collection, preterm infants were below their target oxygen saturation range on average 22% (approximately 5.3 hours) of a 24-hour period (range 2-45%; median 20%; SD 11%). Preterm infants were within their target oxygen saturation range on average 45% (approximately 10.8 hours) of a 24-hour period (range 13-69%; median 49%; SD 15%) during cycle 3. Preterm infants were above their target oxygen saturation range on average 33% (approximately 7.9 hours) of a 24-hour period (range 4-85%; median 27%; SD 21%) during cycle 3. Education cycle 3 for bedside nurses and respiratory therapists occurred November 8 and 9, 2023.

Cycle 4 of data collection occurred November 13 through November 17, 2023, and consisted of 35 oxygen saturation histograms. At the time these 35 histograms were collected, ten of the infants were not receiving supplemental oxygen. During cycle 4 data collection, preterm infants were below their target oxygen saturation range on average 19% (approximately 4.6 hours) of a 24-hour period (range 0-65%; median 17%; SD 18%). Preterm infants were within their target oxygen saturation range on average 32% (approximately 7.7 hours) of a 24-hour period (range 1-75%; median 33%; SD 18%) during cycle 4. Preterm infants were above their target oxygen saturation range on average 49% (approximately 11.8 hours) of a 24-hour period (range 4-99%; median 45%; SD 31%) during cycle 4.



Excluding baseline data collection, a total of 136 oxygen saturation histograms were collected during cycles 1-4 over a period of approximately 6 weeks. During this time, infants less than 32 weeks' gestation spent on average 18% (approximately 4.3 hours) of a 24-hour period below their target oxygen saturation range (less than 90%), 37% (approximately 8.9 hours) of a 24-hour period within their target oxygen saturation range (90-95%), and 44% (approximately 10.8 hours) of a 24-hour period above their target oxygen saturation range (greater than 95%). The line graph above depicts the average percent of time spent below, within, and above target oxygen saturation ranges for baseline and cycles 1-4 (depicted as cycles 1-5 respectively). As seen in the graph, as time spent within the target range increased, so did time spent below target range, but time spent above target range decreased.

Barriers to Success

While implementing this project, I did encounter some unexpected barriers to success. First, the overall census in the unit was lower than average which also meant a lower population that met criteria to be included in this project. This resulted in a longer time spent on data collection during the baseline and first cycles. I also experienced technical difficulties with the monitors not communicating with printers, so I was unable to obtain hard copies of oxygen saturation histograms for evaluation.

Strengths to Overcome Barriers

It was impossible to overcome barriers related to patient populations. In order to overcome technical barriers related to printing of histograms, I used an Excel sheet to log data displayed on the patient monitors. Patient monitors are connected to a central monitor at each of the nursing stations/neighborhoods for closer monitoring of infant vital signs while caretakers are away from patient rooms, so it may be possible that oxygen saturation histograms are available from the central monitor; this could be investigated for future data collection. Also, working closely with information technologies within the clinical site to correct the printing issue is another strategy for improvement.

Discussion

This quality improvement project sought to increase the amount of time preterm infants born at less than 32 weeks' gestation spent within a target oxygen saturation range of 90-95% and answer the following question: when assessed by neonatal bedside nurses and respiratory therapists, do oxygen saturation histograms increase the amount of time preterm infants spend within their oxygen saturation target? The data collected through this project suggest that yes, regular evaluation of oxygen saturation histograms can aid in increasing the amount of time that preterm infants spend within their oxygen saturation target, by as much as 1.2 hours per day, or 4.1 additional days within a 30-day month. At baseline, these infants spent 32% (approximately 7.7 hours) of a 24-hour period within this target range, and 52% (approximately 12.5 hours) of the same 24-hour period above the target range. Over the 45 days of project data collection (cycles 1-4), the amount of time infants spent within their target oxygen saturation range varied from cycle to cycle, but from baseline to cycle 4, the average stayed the same at 32% of a 24-hour period. The greatest improvement was noted from cycle 1 at 29% of a 24-hour period to cycle 2 at 43% of a 24-hour period, equaling an increase of approximately 3.3 hours spent within target range during a 24-hour period. The improvement continued slightly from cycle 2 to cycle 3 at 45% for an additional 0.5 hours spent within target range during a 24-hour period. However, the improvement was not sustained during cycle 4, resulting in a decrease of time spent within target range by approximately 3.1 hours in a 24-hour period. The study by Gentle et al. (2020) demonstrated an approximate increase in time spent within target oxygen saturation range of 2.5 additional days during a 30-day period with regular evaluation of oxygen saturation histograms. The results of this quality improvement project would equate to an approximate increase in 4.1 additional days during a 30-day period spent within target oxygen saturation range with regular evaluation of oxygen saturation histograms by the care team. There are a number of ways regular evaluation of oxygen saturation histograms could be accomplished, including implementing evaluation of oxygen saturation histograms into daily rounds by the medical team, evaluation by nurses at shift change, and regular audits by this nurse practitioner or another auditor at regular intervals. Also, completing data analysis after each cycle of data collection and education could reveal possible areas for improvement or changes to the implementation process that could potentially further increase the amount of time preterm infants spend within their target oxygen saturation range.

Increasing compliance with target oxygen saturation ranges can be accomplished by ensuring alarm limits and parameters are set correctly within the monitors so that bedside nurses and respiratory therapists are notified when infants are outside of their target oxygen saturation range. This notification allows for the manual titration of supplemental oxygen by the care team. The oxygen targeting protocol for the NICU provides specific parameters for alarm limits and when these parameters may be changed, including when infants are and are not receiving supplemental oxygen. Reiteration of the unit-specific protocol can improve compliance with the ordered oxygen saturation targets. At baseline, approximately 50% of the monitors had incorrect alarm limits set and over time I noted a decrease in the number of monitors with incorrect settings. Bedside nurses and respiratory therapists were very receptive to the education provided regarding the unit-specific protocol. There is no clear benchmark for “compliance” with target oxygen saturation ranges, and while 100% of the time is the ideal goal, 50% of the time is a more reasonable and realistic goal. Cycle 3 of this quality improvement project came closest to that goal at 45% of a 24-hour period.

When narrow oxygen targets were implemented in their NICU, Ketko et al. (2015) noted an increase in oxygen saturation alarms from 78 per patient day to 105. This increase in alarms can lead to a higher risk of alarm fatigue among NICU nurses and respiratory therapists, which can potentially lead to decreased compliance with ordered oxygen saturation alarm limits. Sola et al. (2019) noted that bedside staff tend to be more tolerant of hyperoxia because it is felt to be less harmful, and in this project incorrect high oxygen saturation alarm limits are what were found most often. Future rounds of this project could include the number of alarms noted for oxygen saturations outside of the ordered oxygen saturation target in an effort to address and correct the number of false alarms, and potentially decrease alarm fatigue experienced by bedside staff.

When the oxygen targeting protocol was first introduced in this NICU in 2011, it was titled “Oxygen With Love” and the infants were called owls for short. Because they were nicknamed owls, the monitors for these patients had cartoon owls taped to them to remind the care team that these patients had different oxygen saturation limits and needed extra attention with oxygen titration. This visual reminder could be re-implemented to further increase compliance with oxygen saturation targeting for infants less than 32 weeks’ gestation. Following the completion of this initial project, it was noted that oxygen saturation histograms should be included in education for bedside nurses and respiratory therapists in real time so that care providers can see the care they are providing for their patients. Further data collection could also include patient-specific data so that patient-specific changes could be monitored and evaluated over time.

Conclusion

Preterm infants born at less than 32 weeks’ gestation are at higher risk for harmful effects of hypoxia or hyperoxia caused by too much or too little supplemental oxygen. Narrow oxygen targeting guidelines have demonstrated a reduction in these harmful side effects and oxygen saturation histograms have been shown to be a valuable tool for monitoring time spent within these narrow oxygen targets. This quality improvement initiative demonstrated that, when combining review of oxygen saturation histograms with reinforced education of the current unit oxygen targeting protocol, improvement in the amount of time that preterm infants spend within the target oxygen saturation range is possible. Ongoing education of NICU bedside staff as well as frequent audits of patient monitors is needed to further improve compliance with narrow oxygen saturation targets and improve the amount of time preterm infants spend within this target range.

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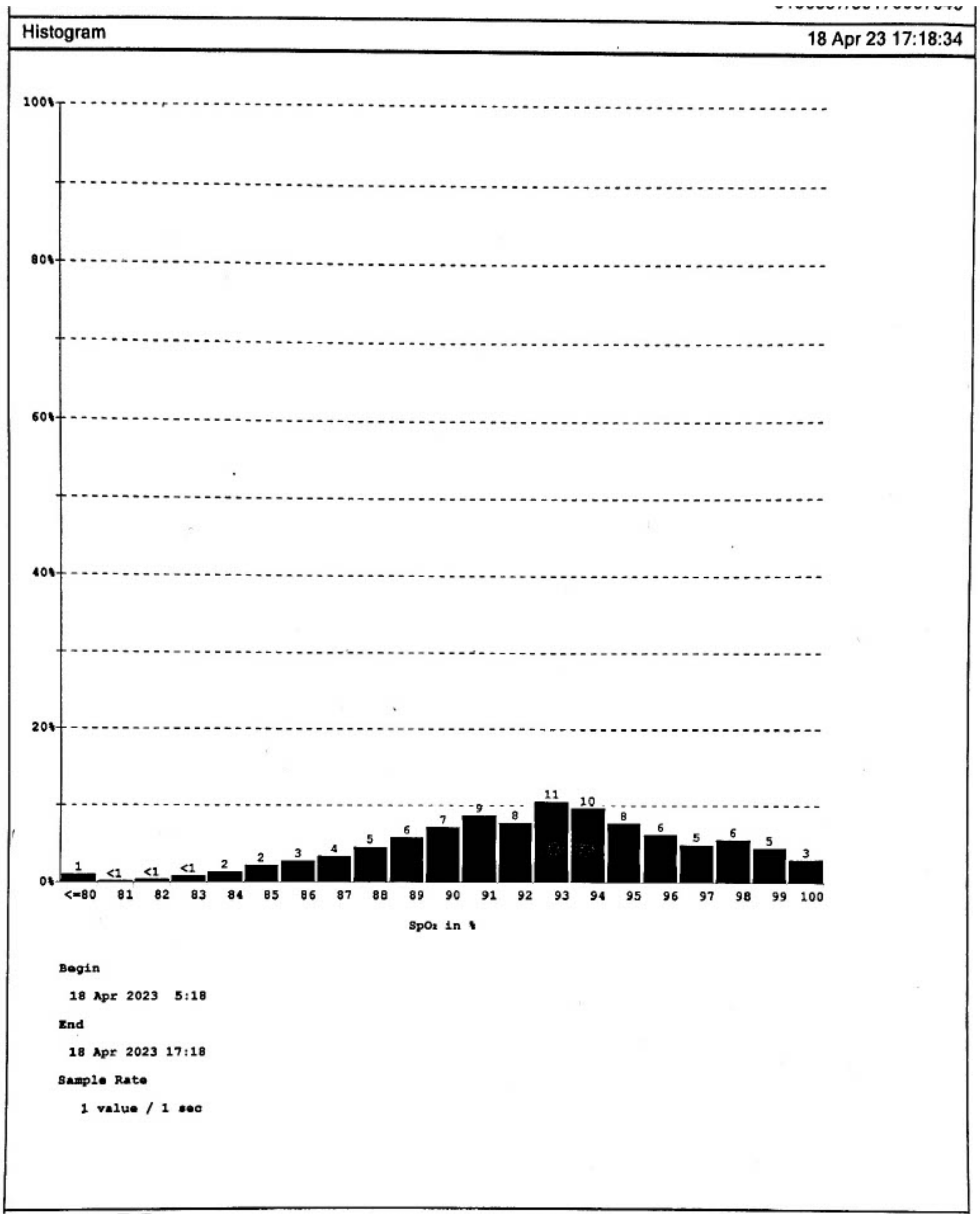
Appendix A. Oxygen Saturation Histogram Example



Appendix B. Data Collection Tool

Cycle	**% Below**	**% Within**	**% Above**	**On Oxygen?**	**Parameters?**
Baseline					
Cycle 1					
Cycle 2					
Cycle 3					
Cycle 4					