Actionable Patient Safety Solutions (APSS) #7A:

Optimal neonatal oxygen targeting

How to use this guide

This guide gives actions and resources for creating and sustaining practices for optimal neonatal oxygen targeting. In it, you'll find:

Patient Safety MOVEMENT

Executive summary checklist

Hypoxia (low blood oxygen) in preterm infants can cause severe harm or death. Giving supplemental oxygen helps avoid hypoxia, but also raises the chance of hyperoxia (excessive blood oxygen). Hyperoxia can cause retinopathy of prematurity (ROP) and increase the risk for other conditions.

Implementing an optimal oxygen targeting guideline can improve neonatal outcomes. Use this checklist to help you prioritize your actions and measure your organization's progress in your neonatal oxygen targeting efforts:

- ☐ Assess your hospital's current methods of oxygen administration and monitoring to find opportunities for improvement
- ☐ Develop an action plan that includes a timeline with concrete goals and milestones for implementing an optimal oxygen guideline for neonates
- ☐ Choose and fund technologies that have been shown to improve neonatal outcomes, such as blenders, pulse oximetry, and heated humidifiers
- ☐ Use blenders in all circumstances when administering oxygen, including the delivery room
- ☐ Use heated humidifiers:
  - o In the delivery room
  - o In the NICU when using CPAP
  - o In all circumstances where the infant is intubated, even for a few minutes
- ☐ For pulse oximetry, select equipment that:
  - ☐ Can measure through motion and low perfusion conditions to avoid inaccurate measurements/false alarms and identify true alarms, and
  - ☐ Has been proven effective for neonatal oxygen targeting
    - Example: Masimo Signal Extraction Technology (SET) pulse oximetry (until another technology is proven to be equivalent)
- ☐ Determine the oxygen targeting guideline that your clinical staff should use:
  - ☐ The SpO2 for a preterm baby breathing supplemental oxygen should not exceed 95
  - ☐ The SpO2 for other larger infants and neonatal patients breathing supplemental oxygen should stay in the range of 88-95% or 90-96%, depending on infant and condition
  - ☐ When SpO2 dips below the desired % or when the low alarm sounds, avoid responding in a way that results in high saturation (>95%)
- ☐ Always keep the monitor alarms on and active when an infant is breathing supplemental oxygen:
  - ☐ Neonates in an intensive care environment should always be monitored by a pulse oximeter capable of monitoring through motion and low perfusion with appropriate alarm limits
  - ☐ The high SpO2 alarm should be set to 95%, depending on the infant
  - ☐ The low SpO2 alarm should be set no lower than 85%
  - ☐ Alarms signaling should receive attention from the nurse, doctor, or respiratory therapist

- ☐ When a baby is not breathing supplemental oxygen or receiving any from respiratory support, but is being monitored for desaturations, set the low SpO2 alarm at 85% and turn off the high alarm

☐ Implement an action plan for including educational activities, workshops, and tools for all members of the neonatal healthcare team

☐ Develop a process for continuous improvement by communicating with staff and implementing measures to improve processes that will help you meet your oxygen targeting goals

☐ Use patient stories – in written and video formats – to identify gaps and inspire change in your staff

What we know about neonatal oxygen targeting

Problems of administering oxygen to newborn infants

It has been clear for many decades that preventing hypoxia in newborns increases survival and lowers the rates of cerebral palsy and other severe neurologic conditions. For this reason, staff should work to prevent hypoxia in newborns.

On the other hand, staff should also prevent hyperoxia. Supplemental oxygen in newborns has been over-used worldwide. This practice can cause various health problems, including:

- Prolonged hospitalizations
- Blindness for life due to retinopathy of prematurity (ROP)
- Cancer in childhood
- Chronic lung disease
- Developmental disabilities, periventricular leukomalacia (a type of brain injury), cerebral palsy, and other oxidant-stress related adverse effects including DNA damage, endocrine and renal damage, decreased myocardial contractility, alveolar collapse, infection, inflammation and fibrosis (Collins, Lorenz, Jetton and Paneth, 2001; Haynes et al., 2003; Sola, Rogido, and Deulofeut, 2007; Klinger, Beyene, Shah, and Perlman, 2005; Sola, 2008; Sola, Saldeño, and Favareto,2008)
- At 5 years of age, motor impairment, cognitive impairment, and severe hearing loss that is 3-4 times more common in children with severe ROP than those without it

Most, if not all, of these complications result from care in the newborn period and cause lasting health issues. These health issues create significant healthcare costs, such as from lengthy hospital stays, and tremendous emotional costs for families.

The standard neonatal oxygen treatment

Hospital practices for oxygen monitoring are variable. Many delivery rooms and neonatal intensive care units worldwide adhere to outdated or otherwise inappropriate protocols. Evidence shows that excessive oxygen administration during the first few minutes of life is noxious. Yet, many delivery rooms worldwide:

- Still administer pure oxygen (100% O_2) unnecessarily
- Do not measure FiO_2

  Do not adequately monitor oxygen saturation (SpO2) levels (Baquero et al., 2011; Shah, Ragaswamy, Govindugari, and Estanol,2012; Bizzarro et al., 2013; Chow, Wright, and Sola, 2003; Deulofeut, Critz, Adams-Chapman, and Sola,2006; SUPPORT Study, 2010)

Evidence shows that stopping inappropriate oxygen administration and increasing the use of oxygen monitoring can significantly lower the rates of these preventable conditions (Sola et al., 2014; Sola, 2015). Hospitals that actively address the administration and monitoring of oxygen in newborn infants to prevent both hypoxia and hyperoxia can realize significant improvements in the quality and safety of healthcare as well as cost savings (Vaucher et al., 2012).

Evidence for change in neonatal oxygen treatment

You can prevent many adverse effects by educating neonatal staff on appropriate oxygen management. This includes measuring oxygen titration with a blender and monitoring an infant's saturation level with pulse oximetry technology that can measure through motion and low perfusion (Chow, Wright, and Sola, 2003).

Research shows evidence for change in neonatal oxygen treatments:

Evidence for delayed cord clamping
It has been estimated that 300,000-700,000 lives could be saved worldwide if 1% of the 130,000,000 global live births who are born at less than 30 weeks receive delayed cord clamping (DCC) which increases arterial oxygen tension at birth and in the first minutes of life (AJOG, 2017).

Evidence for SET
In a 2-phased study of 2 centers that previously used conventional pulse oximetry, both centers changed their neonatal oxygen targeting guideline at the same time, however, only 1 of the centers switched to SET pulse oximetry (Castillo, Deulofeut, Critz, and Sola 2010):

- In the 1st phase of the study:
  - The center using non-SET had no decrease in retinopathy of prematurity
  - The center using SET had a 58% reduction in significant retinopathy of prematurity and a 40% reduction in the need for laser eye treatment
- In the 2nd phase of the study:
  - Both centers used SET and got similar results
- A follow-up study measured outcomes for very low birthweight infants treated with oxygen before and after (304 infants before and 396 infants after) the center switched to SET (Bizzarro et al., 2013). The center's switch to SET resulted in a:
  - 59% reduction in incidence of severe ROP
  - 69% reduction in ROP requiring surgery

Evidence for oxygen targeting guidelines
Research on neonatal oxygen targeting shows how challenging it is to find optimal levels. For example, a study showed that narrow SpO_2 target ranges are difficult to maintain for more than 50-60% of the time (Fiore, 2014).

To date, the "perfect" SpO_2 target range is still not known for all newborns at all times (Saugstad, 2010). A summary of recent publications on extremely premature infants randomly assigned to a lower target SpO_2 intention to treat (85-89%) or higher target SpO_2 intention to treat (91-95%) shows there was neither increased mortality nor serious brain injuries as a result of avoiding hyperoxia in preterm infants (Stenson et al., 2011; Saugstad and Aune, 2011; Castillo, Deulofeut, Critz, and Sola, 2008; Askie et al., 2011).

A recent presentation by Askie et al. (Cochrane review) also shows no difference in the primary outcome of death or disability between a higher (91-95%) versus a lower (85-89%) arterial oxygen saturation. However, a higher rate of NEC occurred at 85-89% and a higher rate of severe ROP occurred at 91-95%. Recently the Committee on Fetus and Newborn of the AAP made clinical recommendations which are included in this document (Cummings and Polin, 2016).

Therefore, avoid an intention to treat with an SpO2 of 85-89%. There are several issues that suggest extreme caution should be used in the interpretation of these randomized controlled trials (Manja, Lakshminrusimha, and Cook,2015; Lakshminrusimha, Manja, Mathew, and Suresh, 2015; Schmidt et al., 2014).

In a recent meta-analysis (Askie, 2018), research suggests that:

- In infants born at less than 28 weeks gestation there was no significant difference in the primary outcome variable of death or major disability at 18-24 months of corrected age when comparing the low SpO_2 target range (85-89%) versus the high one (91-95%)

- In addressing secondary outcome variables, and in post-hoc analysis, an association was found with higher risk for mortality and necrotizing enterocolitis and a lower risk for ROP, when the intention to treat was 85-89%

The accompanying editorial (Bizzarro, 2018) mentions that SpO2 of 91-95% may be better than 85-89%, but that, in clinical practice, SpO2 intention to treat can be different than the 2 intentions studied in the randomized controlled trials.

In summary, in extremely low birth weight infants:

- The ideal oxygen saturation range or intention to treat remains unknown and is often a compromise among negative outcomes associated with either hyperoxemia (such as ROP and BPD) or hypoxemia (such as NEC and death)
- The appropriate SpO2 range for each infant will depend on the type of SpO2 monitor used, gestational age, postnatal age, hemoglobin A concentration, hemoglobin level, oxygen content, cardiac output, clinical diagnosis, and illness severity (Castillo, Deulofeut, Critz, and Sola, 2010)

Despite this variability, it is clear that to improve clinical outcomes, some outdated clinical practices must be stopped and replaced with newer clinical care guidelines aimed at preventing both hyperoxia and hypoxia.

Evidence for SpO2 alarms

Using oxygen saturation alarms and guidelines for limits can help avoid harmful extremes of hyperoxemia or hypoxemia in newborns.

To be most effective:

- Alarms should always be operative – do not disconnect or deactivate alarms
- Busy NICU nurses respond much better to SpO2 alarms rather than to "mental SpO2 target ranges or intention to treat"
- Given the limitations of SpO2 and the uncertainty about the ideal SpO2 intention to treat for infants of extremely low birth weight, wider alarm limits are easier to target
- The lower alarm limit:
  - Generally needs to extend somewhat below the lower SpO2 chosen as the intention to treat
  - Must take into account practical and clinical considerations, and the steepness of the oxygen saturation curve at lower saturations
  - For extremely low birth weight infants, should be set no lower than 85%, although 86-87% may also be appropriate
- The upper alarm limit:
  - Should not be higher than 95% for extremely low birth weight infants while the infant remains on supplemental oxygen or any form of ventilatory support

These considerations highlight the need to introduce clinical guidelines at all institutions caring for newborn infants, and to close the gap between knowledge and practice. The lack of a systematic approach to prevent hypoxia and hyperoxia significantly affects patient safety, quality, and cost of care.

Hospitals, healthcare systems, and all members of the neonatal health care team (RNs, RTs, and MDs) must commit to creating specific and sustainable leadership, action, and technology plans that will help improve safety for newborn infants who require oxygen supplementation.

Leadership plan

Hospital governance, senior administrative leadership, clinical leadership, and safety/risk management leadership need to work collaboratively to optimize neonatal oxygen targeting.

To achieve a goal of zero preventable deaths, leaders need to commit to taking these key actions:

- Implement a plan that includes the fundamentals of change outlined in the National Quality Forum safe practices, including awareness, accountability, ability, and action (National Quality Forum, 2010)

Show leadership's commitment to safer oxygen administration:

- Make sure hospital governance and senior administrative leadership commit to learning about any performance gaps in oxygen management within their own healthcare system
- Make sure that hospital governance, senior administrative leadership, and clinical/safety leadership implement a comprehensive approach to addressing the performance gap, including any gaps of their own
- Allocate a budget for the action plan to be evaluated by governance boards and senior administrative leaders
- Get clinical/safety leadership to endorse the plan and drive implementation across all providers and systems

Create the infrastructure needed to make changes:

- Set a goal date to implement the action plan with measurable quality indicators. "Some is not a number. Soon is not a time." (IHI, n.d.).
- Collect and analyze data on oxygen administration and monitoring to help you:
  - Identify areas for improvement
  - Implement changes
  - Assess outcomes
  - Track your progress toward safer oxygen administration
- Address and re-address these 2 questions for quality improvement: *Are we doing the right things? Are we doing things right?*
- Use patient stories –in written and video formats – to identify gaps and inspire change in your staff
  - **youtube.com/c/patientsafetymovement**

Action plan

Engage leadership and staff:

- Make an organization-wide commitment by administrative, clinical, and patient engagement leaders to address safety in neonatal oxygen targeting
- Create educational activities, workshops, and tools for all members of the neonatal healthcare team
- Develop a systematic process for creating continuous, sustained improvement in oxygen targeting. To do this, communicate with staff and implement measures to improve processes.
- Assess opportunities to improve oxygen administration and monitoring

Establish guidelines for oxygen administration and monitoring:

- Develop an action plan that includes a timeline with concrete milestones for implementing optimal neonatal oxygen targeting guidelines:
  - **Establish oxygen levels:**
    - SpO_2 for a preterm baby breathing supplemental oxygen should not exceed 95%
    - SpO_2 for other larger infants and neonatal patients should stay in the range of 88-95% or 90-96%, depending on the infant and their condition
    - When the saturation or SpO_2 dips below 88%, avoid responding in a way that may cause hyperoxia or high saturation
  - **Use alarms to help monitor oxygen:**
    - Make sure the monitor alarms are always on and active when an infant is breathing supplemental oxygen or is in the neonatal intensive care unit
    - Set the high SpO_2 alarm to 95%, depending on the infant
    - Set the low SpO_2 alarm 85%
    - Alarm signaling should receive attention from a nurse, doctor, or respiratory therapist
    - When a baby is not breathing supplemental oxygen but is being monitored for desaturations, the low SpO_2 alarm should be set at 85% and the high alarm can be turned off

Technology plan

These suggested practices and technologies have shown proven benefit or, in some cases, are the only known technologies for certain tasks. If you know of other options not listed here, please complete the form for the Technology Vetting Workgroup to consider: **https://patientsafetymovement.org/actionable-solutions/apss-workgroups/technology-vetting/**

Select technologies that have been shown to improve neonatal oxygen targeting include:

System or Practice	Available technology
Use blenders in all circumstances when administering oxygen, including the delivery room	
Use heated humidifiers when using CPAP and in all circumstances where the infant is intubated, even for a few minutes, and in the delivery room	
For pulse oximetry, select equipment that: • Can measure through motion and low perfusion conditions to avoid inaccurate measurements/ false alarms and identify true alarms • Is proven effective for neonatal oxygen targeting	

Measuring outcomes

Topic:

Neonatal Oxygen Targeting actively addresses the administration and monitoring of oxygen in newborn infants to prevent both hypoxia and hyperoxia.

Outcome measure formula:

Percent of pre-term babies (under 32 weeks) receiving supplemental oxygen who acquire ROP

Numerator:
Number of pre-term babies (under 32 weeks) receiving supplemental oxygen who acquire ROP

Denominator:
Number of pre-term babies (under 32 weeks) receiving supplemental oxygen who were examined by an ophthalmologist

- This measure is usually displayed as a percentage: Numerator/Denominator *100

Data collection for outcome measure:
Collect all data on pre-term babies (under 32 weeks) who were examined by an ophthalmologist. This will allow you to calculate the outcome measure using the formula above.

Metric recommendations:

Indirect impact:
All pre-term babies (under 32 weeks) who received supplemental oxygen

Direct impact:
The percent of time that pre-term babies (under 32 weeks) who received supplemental oxygen are kept within the accepted SpO_2 range

Lives spared harm:
Lives spared harm = (ROP rate baseline - ROP rate measurement) X pre-term babies under 32 weeks receiving oxygen measurement

Data collection for direct impact:
The percent of time that pre-term babies (under 32 weeks) who received supplemental oxygen are kept within the accepted SpO_2 range

- One approach could be: At minimum, take a random sampling of 3-4 babies on supplemental oxygen on different shifts during 1 week each month. Use different shifts because nursing shifts vary from 6-12 hours across the world and nurse-to-patient ratios also vary. For this reason, the data collection method should be tailored by hospital and by unit.

Conflicts of interest disclosure

The Patient Safety Movement Foundation partners with as many stakeholders as possible to focus on how to address patient safety challenges. The recommendations in the APSS are developed by workgroups that may include patient safety experts, healthcare technology professionals, hospital leaders, patient advocates, and medical technology industry volunteers. Some of the APSSs recommend technologies that are offered by companies involved in the Patient Safety Movement Foundation. The workgroups have concluded, based on available evidence, that these technologies work to address APSS patient safety issues. Workgroup members are required to disclose any potential conflicts of interest.

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