# Safe and Effective Oxygen Use for Inpatient Care of Newborns

DO NO HARM TECHNICAL BRIEF

**Oxygen is important in the care of newborn infants because many conditions that affect babies in the first days of life can result in low levels of oxygen in the body. Hypoxemia, or low level of oxygen in the blood, is a life-threatening condition that results in increased mortality and morbidity. Prematurity and respiratory distress syndrome (surfactant deficiency), pneumonia and other severe infections, asphyxia and difficulties in the transition from fetal to neonatal life can all result in hypoxemia. Supplemental oxygen is an essential lifesaving treatment.**

## Why is Safe Oxygen Use Important?

Access to appropriate oxygen therapy has been demonstrated to reduce death from childhood pneumonia and neonatal respiratory distress. Improved detection of hypoxemia and the safe administration of oxygen has resulted in a 35% reduction in the risk of death from childhood pneumonia in high-burden settings.[1] Historically, the administration and delivery of oxygen with pressure that helps maintain lung inflation has resulted in a dramatic improvement in survival of premature infants.[2] Oxygen therapy remains an essential element in the treatment of newborn respiratory distress, with specialized delivery methods being increasingly used in low and middle-income countries.[3;4]

## How can unsafe oxygen use cause harm?

Oxygen is fundamental for sustaining life, but it is also toxic. Unique developmental vulnerabilities of newborns put them at a greater risk of injury from oxygen use than adults. Injury may occur from high levels of oxygen in the blood, regardless of the administered oxygen concentration, and from exposure of the lungs to high concentrations of oxygen. The two main complications of oxygen use with newborns are retinopathy of prematurity (ROP) and lung injury. The historical success of improving survival of premature infants was tempered by blindness in some survivors that was caused by low, but unmonitored, oxygen exposure. Even with low concentrations of administered oxygen, levels in the blood can rise far above normal. ROP is the abnormal development of blood vessels in the retina of the eye. In its most severe form, ROP can result in blindness. Exposure to supplemental oxygen also produces complications from direct oxygen toxicity to lung tissue. Chronic lung disease (also known as bronchopulmonary dysplasia) is a serious consequence in extremely preterm infants, but cumulative oxygen exposure also leads to lung problems in infancy among moderately preterm babies.[5]

There are multiple ways in which inadequately regulated oxygen use can cause harm. In the special care of newborns the most common include:

- 100% oxygen administration
- Unmonitored oxygen saturation during any supplemental oxygen administration
- "Prophylactic" administration of oxygen to sick or at-risk newborns without clinical indication
- Environmental enrichment with oxygen (i.e. oxygen in incubator)
- Use of non-rebreathing mask or funnel to deliver oxygen
- Interrupted oxygen administration (rotating allocation of available oxygen)

## What are current WHO recommendations for oxygen therapy?

Current WHO recommendations and clinical guidelines address several aspects of oxygen therapy (Table 1).

Clinical indications for oxygen use include resuscitation of preterm infants and advanced resuscitation of term infants as well as the full spectrum of respiratory illness from mild hypoxemia to moderate/severe respiratory distress and respiratory failure. Routine resuscitation of term and moderate-to-late preterm infants begins with bag-and-mask ventilation using room air. However, preterm infants < 32 weeks should receive ventilation beginning with 30% oxygen or air if blended oxygen is not available (rather than 100% oxygen). Oxygen concentration should be guided by blood oxygen saturation levels. Titrating the concentration of oxygen to meet time-specific saturation targets (Table 2). The adjustment of the concentration of oxygen levels should be by 10% (FiO2=0.1) per 30 seconds and must be guided by oxygen saturation levels reached.[6]

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**Table 1: WHO recommendations and clinical guidelines for oxygen therapy in newborns**

| Clinical Circumstance | Patient Group | Oxygen Delivery | Oxygen Monitoring | Other Considerations |
|---|---|---|---|---|
| Resuscitation at birth | Term and > 32 weeks gestation | • Begin positive-pressure ventilation with bag and mask using room air.[7]<br>• Adjust oxygen concentration to achieve time-specific oxygen saturation targets after birth.[6] | Initiate pulse oximetry if heart rate <60 after initial ventilation with room air.[6] | Unhumidified, unheated gases may be used for short periods. |
| | Preterm (< 32 weeks gestation) | • Begin positive-pressure ventilation with bag and mask using 30% oxygen. Use air if blended oxygen is not available.[6]<br>• Adjust oxygen concentration after 30 seconds of adequate ventilation with 30% oxygen to achieve time-specific oxygen saturation targets after birth. | Initiate pulse oximetry monitoring during resuscitation (by 2 min).[6] | Unhumidified, unheated gases may be used for short periods. |
| Mild hypoxemia | Term | • Provide oxygen by nasal cannula.[8]<br>• Adjust oxygen flow rate to achieve oxygen saturation > 90% (88% during transition after birth).[8] | Monitor with pulse oximetry at least twice daily during oxygen therapy.[9] | Unhumidified, unheated gases may be used at flow < 1 L/min, although drying and nasal mucosal injury may occur at higher flow rates.[8;9] |
| | Preterm | • Provide oxygen by nasal cannula.<br>• Adjust oxygen flow rate to achieve oxygen saturation > 88% and < 95%.[9] | Monitor with pulse oximetry at least twice daily during oxygen therapy[9] or continuously if feasible. | All infants born < 32 weeks gestation or <1250 grams and larger preterm infants who received oxygen should be screened for ROP at 4-6 weeks of age.[9] |
| Moderate respiratory distress | Term and preterm–acute | • Provide oxygen with continuous positive airway pressure (CPAP).[6]<br>• Adjust (airway pressure and) oxygen concentration to achieve oxygen saturation > 88% and < 95%.[6] | 100% oxygen should never be used with CPAP.6 Monitor with pulse oximetry at least twice daily during oxygen therapy[9] or continuously if feasible. | Unhumidified, unheated gases may result in airway mucosal drying and injury.[8;9] |
| | Term and preterm - convalescent | • Humidified high-flow nasal cannula oxygen therapy may be useful for transition from CPAP/PPV. | Monitor with pulse oximetry at least twice daily during oxygen therapy[9] or continuously if feasible. | Unhumidified, unheated gases may result in airway mucosal drying and injury.[8;9] |
| Severe respiratory distress | Term and preterm | Care for infants with severe respiratory distress should be provided in facilities where intubation, ventilator care, blood gas analysis, newborn nursing and continuous electronic monitoring are available.[6] | | Surfactant replacement therapy recommended for intubated and ventilated newborns with respiratory distress syndrome in advanced settings.[6] |

Pulse oximetry, the non-invasive measurement of arterial oxygen saturation, is crucial to diagnose hypoxemia and monitor oxygen administration to prevent toxicity. Infants may normally have slightly lower saturations in the first hours after birth (> 88%) and at high altitude. The ideal saturation range for ongoing care of preterm infants has not been fully established despite several large, coordinated, multicenter clinical trials.[10;11;12;13] Many authorities agree that saturations between 90-95% minimize both low and high oxygen levels that have been associated with death, neurodevelopmental impairment and ROP.[14;15;16]

**Table 2: Time-specific oxygen saturation targets in resuscitation of preterm infants[6]**

| Time after birth | Preterm infants |
|---|---|
| 2 min | 55-75% |
| 3 min | 65-80% |
| 4 min | 70-85% |
| 5 min | 80-90% |
| 10 min | 85-95% |

## What systems are needed for safe oxygen use?

There are many special considerations when caring for infants who require oxygen therapy. These involve unique aspects of neonatal physiology and development and require the understanding of nurses, physicians, technicians, biomedical engineers, administrators and parents. The requirements for safe oxygen use in newborns include:

- Systems for delivering different oxygen concentrations (blenders to provide 21% to 100% oxygen)
- Non-invasive systems for measuring oxygen levels in the blood (pulse oximetry)
- Adequate number of trained staff who understand the importance of controlling oxygen levels

## What are the current evidence-based best practices?

**Prevention of unnecessary oxygen exposure**: Appropriate administration of antenatal corticosteroids to women with threatened preterm birth from 24 to 34 weeks of gestation can reduce the incidence and severity of respiratory distress syndrome among their newborn infants.[6,17] When oxygen therapy is required, during resuscitation or later during inpatient care, minimizing the concentration and duration of oxygen exposure through strict monitoring is key to avoiding increased need for oxygen and resultant complications. Pulse oximetry provides non-invasive monitoring of blood oxygen levels episodically or continuously. Involving parents in skin-to-skin contact and developmentally supportive care of newborns can reduce agitation and desaturation, and thus limit unnecessary oxygen exposure.

**Clinical competencies for safe delivery of oxygen**: Nurses, midwives, physicians and other health professionals who care for newborns receiving oxygen therapy should have specific training and demonstrated skills in:

- Indications for oxygen use
- Selection, set-up and care of delivery systems
- Prevention of excessive oxygen concentrations
- Hygiene, infection prevention and thermal protection when delivering oxygen
- Airway suctioning
- Monitoring frequency and adherence to target saturation ranges
- Documentation and use of data to review process and outcome measures
- Awareness of complications

Facility-specific standard operating policies and procedures, as well as clinical treatment guidelines, and availability of blenders, pulse oximeters, gas heaters/humidifiers are key to improving safe use of oxygen.

**Biomedical safety and maintenance of oxygen delivery systems**: Biomedical engineers should oversee the systems used to deliver and monitor a continuous supply of oxygen. This may involve an oxygen production facility and extensive distribution infrastructure or focus on point-of-care delivery systems such as oxygen cylinders and oxygen concentrators. Maintenance of delivery and monitoring systems for oxygen requires scheduled calibration, cleaning, electrical safety checks and repair/replacement of durable and consumable elements (e.g. probes, bacterial filters).

**Surveillance and follow-up of newborns treated with oxygen**: Newborns who are treated with oxygen need to be monitored with pulse oximetry and have oxygen saturations kept in the safe range. Newborns who have received oxygen therapy must be screened for evidence of direct and indirect toxicity – specifically, lung injury and retinopathy of prematurity.

**Table 3: Devices for safe oxygen delivery in different clinical settings**

| Device | Clinical Utility | Flowmeter | Blender | Humidification | Safety Considerations |
|---|---|---|---|---|---|
| Head hood | Initial assessment, stabilization during transition | L/min | yes | Unheated/ optional | Maintain adequate flow for volume of hood to avoid carbon dioxide buildup. |
| Low-flow nasal cannula | Mild hypoxemia in acute or convalescent phase | mL/min | no | Unheated/ optional | Exact oxygen concentration delivered is not measured; concentration delivered to lungs reflects the mixture of oxygen and entrained air. |
| High-flow nasal cannula | Moderate hypoxemia or need for distending airway pressure | L/min | yes | Heated | Airway plugging and mucous membrane irritation result from inadequate humidification. |
| Continuous positive airway pressure (CPAP) | Moderate respiratory distress with need for distending airway pressure | L/min | yes | Heated | Airway pressure is measured in cm H2O near patient interface, which is accomplished with nasal prongs or mask. |
| Positive-pressure ventilation (PPV) | Severe respiratory distress/respiratory failure | L/min | yes | Heated | Peak and end-expiratory airway pressure and tidal volume measured near patient interface, which is accomplished with endotracheal tube or nasal prongs (NIPPV). |

# What actions can be taken to improve oxygen use and health outcomes?

**Actions at many levels within the health system are needed to assure safe oxygen use.**

### Policy Makers

- Regionalization of care at various levels of the health system with referral and transport to more advanced respiratory support
- Clinical guidelines for safe oxygen use and ROP screening
- System-wide staffing norms and requirements
- Capital investments and commitment to ongoing financing

### Program Planners/Implementers

- Matching infrastructure needs to level of care provided
- Procurement planning for a sustainable supply of equipment and related consumables specifically designed for neonatal use
- Supply chain management for oxygen, with potential plans for manufacturing capacity
- Standard operating procedures for operation and maintenance, including procurement plan for spare parts
- Capacity building for health workers including pre-service and in-service training programs

### Facility Managers/Administrators

- Infrastructure and maintenance support for oxygen supply
- Procurement of equipment and supplies specific for delivery of oxygen therapy to neonates (oxygen blenders, pulse oximeters, oxygen heaters/humidifiers)
- Adequate human resources to provide care and monitoring
- Use of indicators to monitor trends and improve oxygen use and patient outcomes

### Health Care Providers (Physicians, Nurses, Midwives, Ancillary Staff)

- Reducing the need for oxygen/minimizing unnecessary exposure
- Understanding and utilizing techniques for safe delivery of oxygen and improving the process and outcomes of care
- Screening infants treated with oxygen to detect and treat ROP

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