

# Inhaled Nitric Oxide for Infants

Guideline Number: MMG169.B  
 Effective Date: March 1, 2021

[Instructions for Use](#)

Table of Contents	Page
<a href="#">Coverage Rationale</a> .....	1
<a href="#">Applicable Codes</a> .....	1
<a href="#">Description of Services</a> .....	2
<a href="#">Clinical Evidence</a> .....	2
<a href="#">U.S. Food and Drug Administration</a> .....	6
<a href="#">References</a> .....	7
<a href="#">Guideline History/Revision Information</a> .....	8
<a href="#">Instructions for Use</a> .....	8

Related Policies
None

## Coverage Rationale

Inhaled nitric oxide (iNO) is proven and medically necessary for treating term or near-term infants (at least 34 weeks gestation at birth) with hypoxic respiratory failure or echocardiographic evidence of persistent pulmonary hypertension of the newborn (PPHN) and all of the following:

- Absence of congenital diaphragmatic hernia (CDH)
- Failure of conventional treatments (e.g., mechanical ventilation)

Note: In the postoperative management of pulmonary hypertension associated with heart or lung surgery in infants, iNO is a clinically accepted option and will be covered as bridge therapy during the acute recovery phase.

Due to insufficient evidence of efficacy, iNO is unproven and not medically necessary for treating all other newborns including but not limited to:

- Newborns with CDH
- Preterm newborns who are less than 34 weeks gestation at birth

## Applicable Codes

The following list(s) of procedure and/or diagnosis codes is provided for reference purposes only and may not be all inclusive. Listing of a code in this guideline does not imply that the service described by the code is a covered or non-covered health service. Benefit coverage for health services is determined by the member specific benefit plan document and applicable laws that may require coverage for a specific service. The inclusion of a code does not imply any right to reimbursement or guarantee claim payment. Other Policies and Guidelines may apply.

CPT Code	Description
94799	Unlisted pulmonary service or procedure

*CPT® is a registered trademark of the American Medical Association*

## Description of Services

Hypoxic respiratory failure can occur in infants of all gestational ages. In the preterm infant, respiratory failure typically presents secondary to an insufficiency of surfactant, a soap-like material that lines the air-spaces of the lungs. Respiratory failure in the term and near-term newborn can result from conditions such as sepsis, meconium aspiration at birth, pulmonary hypoplasia or congenital diaphragmatic hernia (CDH). These conditions can cause elevated pressure in the pulmonary vessels. The classic characteristics of persistent pulmonary hypertension of the newborn (PPHN) include increased pulmonary vascular resistance, right-to-left shunting and severe hypoxemia (McLaughlin et al., 2009).

Treatment of the preterm infant (born at less than 34 weeks gestation) with respiratory failure usually involves administration of exogenous surfactant and mechanical ventilation. In the term and near-term ( $\geq 34$  weeks gestation) newborn, management of acute respiratory failure could also include administration of oxygen, continuous positive airway pressure, conventional or high-frequency ventilation, pharmacological intervention or extracorporeal membrane oxygenation (ECMO) using a heart/lung machine.

Inhaled nitric oxide (iNO) therapy involves the administration of gaseous nitric oxide which dilates pulmonary vessels in ventilated areas and decreases pulmonary vascular resistance. Because nitric oxide affects vascular muscle tone regulation in the pulmonary system, it has become a treatment for hypoxemic respiratory failure which is associated with high pulmonary vascular pressure. Inhaled nitric oxide is used as one of the treatments for newborns with hypoxic respiratory failure to improve oxygenation and reduce the need for ECMO. Inhaled nitric oxide may be a treatment option for the postoperative management of pulmonary hypertension associated with heart or lung surgery in infants. While iNO is generally considered safe, it results in increased levels of methemoglobin and has recently been associated with a more than eight-fold risk of childhood cancer (Dixon et al., 2018). These possible harms should be weighed against the demonstrated benefits in selected populations of infants.

## Clinical Evidence

### Hypoxic Respiratory Failure or Persistent Pulmonary Hypertension of the Newborn (PPHN) in Term or Near-Term Infants

Wang et al. (2019) conducted a systematic review and meta-analysis to determine whether the inhalation of nitric oxide (NO) could improve oxygenation and reduce rate of death or use of extracorporeal membrane oxygenation (ECMO) among infants born at 34 weeks gestation or more. Nine randomized controlled trials (RCTs) with a total of 856 participants were included in this meta-analysis. The analyses revealed that the iNO group was less likely to develop the combined outcome of death or use of ECMO than the control group. This difference was clinically (relative decrease in risk of 34%) and statistically significant. According to the authors, the use of NO inhalation is recommended for respiratory failure among infants born at or near term.

In a Cochrane systematic review and meta-analysis, Barrington et al. (2017a) assessed whether iNO treatment of hypoxemic term and near-term newborn infants improves oxygenation and reduces rate of death or use of ECMO, or affects long-term neurodevelopmental outcomes. A total of 17 randomized controlled studies were identified for inclusion in the review. Some of the studies were limited to subjects with PPHN, but some were not. Most of the reported results were obtained from 10 studies of moderate to high quality, which compared iNO versus standard therapy without iNO. Six smaller trials enrolled infants with moderate severity of illness scores and randomized them to immediate iNO treatment or iNO treatment only after deterioration to more severe criteria. As infants with congenital diaphragmatic hernia (CDH) may respond differently from other near-term infants, results for these infants were evaluated separately. The authors found that hypoxemic term and near-term infants treated with iNO appears to have improved outcomes by reducing the incidence of the combined endpoint of death or use of ECMO (high-quality evidence). Infants who received iNO at less severe criteria did not have better clinical outcomes than those who were enrolled but received treatment only if their condition deteriorated. The data did not suggest that iNO given earlier was more beneficial. Incidence of disability, incidence of deafness and infant development scores were all similar between participants who received iNO and those who did not. The authors concluded that iNO is effective at an initial concentration of 20 ppm for term and near-term infants with hypoxic respiratory failure who do not have a diaphragmatic hernia.

Wu et al. (2016) conducted an RCT (not included in the Wang or the Barrington meta-analysis) to investigate the effect of iNO for treating PPHN. Eighty-six infants with neonatal pulmonary hypertension were included in this study. Twelve percent of these infants were premature, but it is unclear whether they were born before or after 34 weeks of gestation. The infants were

randomly divided into an iNO group (n=43) or a control group (n=43). Infants in the control group were treated with high-frequency oscillatory ventilation, while those in the observation group were treated with high-frequency oscillatory ventilation combined with iNO therapy. Pulmonary artery pressure decreased at each time point, and the levels in the iNO group were lower than those of the control group. The differences were statistically significant. The duration of mechanical ventilation, duration of oxygen therapy, and mortality in the iNO group were significantly lower than those of the control group. The investigators concluded that the use of iNO to treat PPHN can significantly improve oxygen supply, reduce pulmonary artery pressure, shorten treatment time, and reduce mortality.

## ***Professional Society Statements and Other Guidelines***

### **American Academy of Pediatrics (AAP)**

The AAP published a policy statement in 2000 (reaffirmed in 2010) on the use of iNO in infants with respiratory distress. The AAP supports the use of iNO for the indications, dosing, administration and monitoring outlined on the product information label and approved by the FDA.

### **American Heart Association (AHA) and American Thoracic Society (ATS)**

The AHA and ATS's guideline on pediatric pulmonary hypertension recommends the use of iNO to reduce the need for ECMO in term and near-term infants with PPHN or hypoxemic respiratory failure who have an oxygenation index that exceeds 25 [Class I; Level of Evidence A (the procedure/treatment was deemed useful/effective with sufficient evidence from multiple randomized trials or meta-analyses)] (Abman et al., 2015).

### **Preterm Newborns**

The evidences show no clinically or statistically significant benefit of iNO among premature newborns born at less than 34 weeks for the treatment of respiratory distress syndrome (RDS) or the prevention or treatment of bronchopulmonary dysplasia (BPD). Furthermore, the evidence (Barrington et al., 2017b) suggests possible harm for that population [grade 3 or 4 intraventricular hemorrhage (IVH)].

Greenough et al. (2020) conducted a systematic review to evaluate the long-term effects of iNO usage at 7 years of age for prevention of bronchopulmonary dysplasia (BPD) in premature infants. A 7-year follow-up was undertaken of infants who had been entered into the European Union Nitric Oxide (EUNO) trial, a multicenter, double-blind, randomized, placebo-controlled trial of iNO for prevention of BPD in premature infants born between 24 and 28 weeks plus six days of gestation. At 7 years, survival and hospital admissions since the 2-year follow-up, home oxygen therapy in the past year, therapies used in the previous month and growth assessments were determined. Questionnaires were used to compare general health, well-being, and quality of life. A total of 305 children were assessed. No deaths were reported. This study demonstrated that iNO had no significant effect on mortality, growth, hospitalization, outpatient therapy, medication use, HRQOL and overall health outcomes at 7 years of follow-up in premature infants. This study has strengths and some limitations. This is the first study to assess the outcomes of very prematurely born infants at 7 years of age who had been entered into a neonatal randomized trial of iNO. A major limitation was that 11 of the original 35 study centers did not participate in the 7-year follow-up. Nevertheless, the iNO and placebo groups were well balanced, with characteristics like those of the original randomized population which reflects the overall population. A study limitation was that a proportion of the population was not intubated, and hence they may not have received enough iNO. In conclusion, iNO for prevention of BPD in very premature infants with respiratory distress did not result in long-term benefits or adverse long-term consequences. As a result, routine use of iNO cannot be recommended for prevention of BPD in preterm infants.

A Hayes report evaluated the use of iNO therapy to reduce mortality and prevent early lung injury in preterm newborns (less than 35 weeks gestation at birth). This systematic review was designed to identify good quality systematic reviews and health technology assessments, as well as subsequently published primary data to update the findings of earlier reviews. The review found that a consistent body of high quality evidence indicates that early rescue iNO does not increase survival, decrease pulmonary morbidity, or improve neurodevelopmental outcomes in preterm infants who require respiratory support. Hayes found moderate quality evidence indicating that iNO use does not decrease the risk of BPD. The Hayes review also found moderate quality evidence indicating that routine prophylactic iNO use does not improve outcomes in preterm infants with respiratory failure (Hayes, 2018).

Askie et al. (2018) conducted a meta-analysis of selected studies to assess whether iNO improves survival without BPD for preterm African American infants. The review included 3 randomized, placebo-controlled trials that enrolled infants born at less

than 34 weeks of gestation receiving respiratory support, had at least 15% of African American participants, and used a starting iNO of greater than 5 parts per million with the intention to treat for 7 days minimum. In contrast with participants of other races, African American infants had a significant reduction in the composite outcome of death or BPD with iNO treatment: 49% treated vs 63% controls. There was also a significant difference between races of iNO treatment for BPD in survivors, with the greatest effect in African American infants. There were no differences between racial groups for death, the use of postnatal steroids, pulmonary air leak, pulmonary hemorrhage, or other measures of respiratory support. The investigators concluded that iNO therapy should be considered for preterm African American infants at high risk for BPD. As subgroup analyses by race was not pre-specified in all included studies, these findings should be considered post hoc and hypothesis-generating rather than conclusive evidence of benefit in African American infants.

In a Cochrane systematic review, Barrington et al. (2017b) analyzed the effects of iNO treatment on survival and brain or lung injury in preterm newborn infants with hypoxic respiratory failure. A total of 17 randomized controlled studies were identified for inclusion in the review. These trials studied preterm infants with very different baseline characteristics; therefore, it was decided to divide them into three groups: (1) infants treated over the first three days of life because of defects in oxygenation, (2) preterm infants with evidence of pulmonary disease treated routinely with iNO and (3) infants treated later (after three days of age) because of elevated risk of BPD. Eight studies addressed iNO use for early rescue with no significant effect on mortality or BPD demonstrated. The routine use of iNO for infants with pulmonary disease was addressed in four studies and no significant decrease in death or BPD was reported. The authors did not find any clinically or statistically significant benefit of iNO in this population. Furthermore, while no clear effect was found on the incidence of neurodevelopmental impairment or on the frequency of the IVH of any grade, the meta-analysis suggested a possible increased risk of grade 3 or 4 IVH with iNO. The investigators concluded that iNO does not appear to be effective as rescue therapy for the very ill preterm infant and indicated that early routine use of iNO in preterm infants with respiratory disease does not prevent serious brain injury or improve survival without BPD.

In an RCT not included in the systematic reviews above, Hasan et al. (2017) evaluated whether the administration of iNO to preterm infants requiring positive pressure respiratory support improves the rate of survival without BPD. An intent-to-treat RCT analysis was performed for participants at 33 US and Canadian neonatal intensive care units, including 451 neonates younger than 30 weeks' gestation receiving mechanical ventilation or positive pressure respiratory support on postnatal days 5 to 14. Placebo (nitrogen) or iNO initiated at 20 ppm was decreased to 10 ppm between 72 and 96 hours after starting treatment and then to 5 ppm on day 10 or 11. Infants remained on the 5-ppm dose until completion of therapy (24 days). The primary outcome was the rate of survival without BPD at 36 weeks' postmenstrual age (PMA). In total, 222 infants received placebo, and 229 infants received inhaled nitric oxide. Survival without BPD at 36 weeks' PMA was similar between the placebo and inhaled nitric oxide groups (31.5% vs 34.9%). Rates for severe BPD, postnatal corticosteroid use for BPD and the mean days of positive pressure respiratory support, oxygen therapy, and hospitalization were equivalent between the two groups. No differences in the incidence of common morbidities were observed. Respiratory outcomes on discharge to home, at 1 year, and at age 18 to 24 months' PMA and neurodevelopmental assessments at 18 to 24 months' PMA did not differ between groups. This study provides additional support to the systematic reviews above for the lack of benefit of iNO in infants younger than 30 weeks at birth.

## ***Professional Society Statements and Other Guidelines***

### **American Academy of Pediatrics (AAP)**

In 2014, the AAP Committee on Fetus and Newborn released guidance on the use of inhaled nitric oxide (iNO) in preterm infants. The AAP indicated that neither rescue nor routine use of nitric oxide in preterm infants with respiratory failure improves survival (Grade of recommendation: strong; Evidence quality: A). The AAP also states that evidence does not support the use of iNO for preventing BPD, severe IVH, or other neonatal comorbidities in preterm infants with respiratory failure (Grade of recommendation: strong; Evidence quality: A) (Kumar, 2014).

The AAP published a policy statement in 2000 (reaffirmed in 2010) on the use of iNO in infants with respiratory distress. This policy statement indicates that there is limited data on the use of low-dose iNO for hypoxic preterm neonates. The authors state that available data suggests iNO improves oxygenation but does not improve survival in this patient population.

### **Canadian Pediatric Society (CPS)**

The CPS Fetus and Newborn Committee practice point indicates that the role of iNO in managing preterm infants has not been established (Canadian Pediatric Society, 2017).

## European Paediatric Pulmonary Vascular Disease Network

The European Paediatric Pulmonary Vascular Disease Network has published consensus statements regarding iNO for the treatment of preterm and term neonates, infants and children. The network recommended that “the preterm infant with respiratory failure should not receive iNO for the prevention of BPD and associated pulmonary hypertension if not enrolled in a rigorously conducted randomized clinical trial” [Class of recommendation III (Evidence or general agreement that the given treatment or procedure is not useful/effective, and in some cases may be harmful (is not recommended); Level of Evidence: A (Data derived from multiple randomized clinical trials or meta-analyses)] (Hilgendorff et al., 2016).

## National Institutes of Health (NIH)

In 2011, the NIH released a Consensus Development Conference Statement on the use of iNO therapy for premature infants. The statement was developed by a conference panel consisting of 16 members from pertinent fields and was based on published scientific literature and evidence presented in an open forum. The statement indicates that early routine, early rescue, or later rescue use of iNO is not recommended for preterm infants less than 34 weeks gestation requiring respiratory support (Cole et al., 2011).

## Newborns with Congenital Diaphragmatic Hernia (CDH)

The benefits of iNO are not clear in newborns with CDH and possible harm is a concern in this population. Systematic reviews of randomized controlled trials suggest that iNO is ineffective or has minimal effect in newborns with CDH. The evidence indicates that the net health outcome of iNO was not improved for newborns with CDH beyond temporary oxygenation improvement. A few observational studies were recently published regarding CDH but no recent randomized controlled trials for CDH were identified that would impact the conclusions of the systematic reviews.

Lawrence et al. (2019) in a comparative study, evaluated which patients with congenital diaphragmatic hernia (CDH) and pulmonary hypertension (PH) benefit from inhaled nitric oxide (iNO) treatment by comparing characteristics and outcomes of iNO responders to nonresponders. A retrospective chart review of infants with CDH treated between 2011 and 2016. In a subset of patients, iNO was initiated for hypoxemia or echocardiographic evidence of extrapulmonary right to left shunting. Initial post-treatment blood gases were reviewed, and patients were classified as responders (increased PaO<sub>2</sub> >20 mm Hg) or nonresponders. Baseline characteristics, echocardiograms and outcomes were compared between groups with Fisher exact tests and Mann-Whitney t tests, as appropriate. During the study period, 95 of 131 patients with CDH (73%) were treated with iNO. All patients with pretreatment echocardiograms (n = 90) had echocardiographic evidence of PH. Thirty-eight (40%) patients met treatment response criteria. Responders had significant improvements in PaO<sub>2</sub> alveolar-arterial gradient and PaO<sub>2</sub> to FiO<sub>2</sub> ratio. Nonresponders were more likely to have left ventricular systolic dysfunction on echocardiogram. Responders were less likely to require extracorporeal membrane support. While iNO is associated with improved oxygenation in a subpopulation of CDH neonates with PH and normal LV systolic function, LV systolic dysfunction was associated with lack of response to treatment and subsequent ECMO treatment, potentially suggesting that pulmonary vasodilation and increased pulmonary venous return could precipitate cardiorespiratory failure in this subset of patients. Study limitations included this was retrospective and a small sample size. Also, diastolic function and additional markers of systolic function (tissue Doppler imaging, speckle tracking echo, etc) should be evaluated as other potential echocardiographic predictors of response. Ventilator measures were not followed other than mode and FiO<sub>2</sub> during the treatment period, therefore the contribution of ventilator management to oxygenation improvements could not be assessed. Lastly, the institutional practice was to initially resuscitate neonates with CDH and with 50% O<sub>2</sub>, but still many patients in this series were treated with 100% O<sub>2</sub> which could have dampened a potential iNO treatment effect. As a result of this study, the use of iNO in infants with CDH with PH and significant LV dysfunction is not recommended. Future studies are needed to identify additional patient characteristics and echocardiographic parameters that predict iNO response to further refine patient selection for therapy.

Wang et al. (2019) conducted a systematic review and meta-analysis to determine whether the inhalation of nitric oxide (NO) could improve oxygenation and reduce rate of death or use of ECMO. The main findings for infants without CDH are reported above. The analyses for the subgroup of participants with CDH showed no clear benefit on oxygenation.

In a Cochrane systematic review and meta-analysis, Barrington et al. (2017a) assessed whether iNO treatment of hypoxemic term and near-term newborn infants improves oxygenation and reduces rate of death or use of ECMO, or affects long-term neurodevelopmental outcomes. The main findings for infants without CDH are reported above. Analyses limited to patients with

CDH failed to demonstrate a benefit and suggest a possible harm of iNO for the combined outcome of death or use of ECMO, despite a possible benefit on short-term oxygenation.

Puligandla et al. (2015) performed a systematic review on the management of CDH. The available studies indicated iNO can “transiently improve oxygenation”, but in the two randomized controlled trials (Neonatal Inhaled Nitric Oxide Study Group, 1997; Clark et al., 2000) that analyzed data on CDH, there was no evidence for benefits on the relevant primary outcome (death or need for ECMO) and the data suggested possible but not statistically significant harm on this combined outcome. The authors recommended that multi-institutional studies be done to identify best practices.

### ***Professional Society Statements and Other Guidelines***

#### **The American Association for Respiratory Care (AARC)**

The AARC published an evidence-based clinical practice guideline on iNO for neonates with acute hypoxic respiratory failure in 2010. This guideline recommends that iNO should not be used routinely in newborns with CDH (DiBlasi et al., 2010).

#### **Canadian Pediatric Society (CPS)**

The CPS Fetus and Newborn Committee practice point indicates that iNO use is not effective for most infants with CDH (Canadian Pediatric Society, 2017).

### **Postoperative Management of Pulmonary Hypertension Associated with Heart or Lung Surgery in Infants**

Evidence for the benefits or harm of iNO is inconclusive for this heterogeneous and relatively rare population of patients. However practice-based guidelines suggest that individual patients may benefit from bridge therapy during the acute recovery phase.

In an updated Cochrane systematic review, Bizzarro et al. (2014) compared the effects of postoperative administration of iNO versus placebo or conventional management, or both, on infants and children with congenital heart disease (CHD) and pulmonary hypertension. Randomized and quasi-randomized controlled trials comparing iNO with placebo or conventional management, or both were included in the review. The original review was published in 2005 and updated in 2008. The authors reran the searches to December 2013 and found four randomized clinical trials involving 210 participants aged from one day to 17 years with PH either in the preoperative (one study) or postoperative period (three studies). The authors found it difficult to draw valid conclusions given concerns regarding methodologic quality, sample size, and heterogeneity. The authors concluded that the results of this review do not appear to show any significant clinical benefit with the use of postoperative iNO to treat pulmonary hypertension in children with CHD. However, based on broad confidence intervals, the findings of this review are largely inconclusive and unable to exclude clinically significant benefits or harms.

### ***Professional Societies***

#### **American Heart Association (AHA) and American Thoracic Society (ATS)**

In regards to postoperative PH, the AHA and ATS guideline on pediatric PH recommends that in addition to conventional postoperative care, iNO and/or inhaled prostacyclin (PGI<sub>2</sub>) should be used as the initial therapy for PH crises (PHCs) and failure of the right side of the heart [Class I; Level of Evidence B (the procedure/treatment was deemed useful/effective with data derived from a single randomized trial or nonrandomized studies)] (Abman et al., 2015).

## **U.S. Food and Drug Administration (FDA)**

This section is to be used for informational purposes only. FDA approval alone is not a basis for coverage.

Nitric oxide gas is regulated by the FDA as a drug. A complete nitric oxide delivery system is comprised of a nitric oxide administration apparatus, a nitric oxide gas analyzer, and a nitrogen dioxide gas analyzer.

INOMax® (nitric oxide gas) was initially cleared by the FDA in December 1999. INOMax is indicated for treatment of term and near-term (>34 weeks) neonates with hypoxic respiratory failure associated with clinical or echocardiographic evidence of pulmonary hypertension. Multiple supplemental approvals have been issued for INOMax. INOMax is not approved for use in

preterm infants ( $\leq 34$  weeks). INOmax is contraindicated in infants known to be dependent on right-to-left shunting. See the following websites for more information:

- <https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpmn/pmn.cfm?ID=K061901>.
- <http://inomax.com/wp-content/uploads/2016/02/INOmax-PI-web-2015-10.pdf>.
- <https://www.accessdata.fda.gov/scripts/cder/daf/index.cfm?event=overview.process&ApplNo=020845>.

(Accessed January 19, 2021)

Noxivent<sup>®</sup> received approval on October 2, 2018, based on the original New Drug Application (NDA) for INOmax. See the following website for more information:

<https://www.accessdata.fda.gov/scripts/cder/daf/index.cfm?event=overview.process&ApplNo=207141>.

(Accessed January 19, 2021)

The INOmax delivery system received FDA clearance in September 2006. This delivery system can administer the iNO in conjunction with a ventilator or other mechanical gas administration system such as INOmax DSIR<sup>®</sup>, INOmax DS<sup>®</sup> and INOvent<sup>®</sup>. These delivery systems allow the administration of an operator-determined amount of nitric oxide and should be calibrated using a precise calibration mixture of nitric oxide and nitrogen dioxide such as INOcal<sup>®</sup>. They also provide monitoring of inspired O<sub>2</sub>, NO<sub>2</sub> and NO with an alarm system. See the following website for more information:

<https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpmn/pmn.cfm?ID=K061901>. (Accessed January 19, 2021)

The GeNOSyl<sup>™</sup> MV-1000 nitric oxide delivery device received 510(K) clearance from the FDA in 2012. It is approved to provide a constant set concentration of nitric oxide to the patient via mechanical ventilation and also includes monitoring of inspired O<sub>2</sub>, NO<sub>2</sub> and NO with an alarm system. See the following website for more information:

<https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpmn/pmn.cfm?ID=K120216>. (Accessed January 19, 2021)

## References

- Abman SH, Hansmann G, Archer SL, et al.; American Heart Association Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation; Council on Clinical Cardiology; Council on Cardiovascular Disease in the Young; Council on Cardiovascular Radiology and Intervention; Council on Cardiovascular Surgery and Anesthesia; and the American Thoracic Society. Pediatric pulmonary hypertension: Guidelines from the American Heart Association and American Thoracic Society. *Circulation*. 2015 Nov 24;132(21):2037-99.
- American Academy of Pediatrics (AAP). Committee on Fetus and Newborn. Use of inhaled nitric oxide. *Pediatrics*. 2000 (reaffirmed in 2010);106(2 Pt 1):344-345.
- Askie LM, Ballard RA, Cutter GR, et al.; Meta-analysis of Preterm Patients on Inhaled Nitric Oxide Collaboration. Inhaled nitric oxide in preterm infants: An individual-patient data meta-analysis of randomized trials. *Pediatrics*. 2011;128(4):729-739.
- Askie LM, Davies LC, Schreiber MD, et al. Race effects of inhaled nitric oxide in preterm infants: an individual participant data meta-analysis. *J Pediatr*. 2018;193:34-39.e32.
- Barrington KJ, Finan N, Pennaforte T. Inhaled nitric oxide for respiratory failure in preterm infants. *Cochrane Database Syst Rev*. 2017b Jan 3;1:CD000509.
- Barrington KJ, Finan N, Pennaforte T, et al. Nitric oxide for respiratory failure in infants born at or near term. *Cochrane Database Syst Rev*. 2017a Jan 5;1:CD000399.
- Bizzarro M, Gross I, Barbosa FT. Inhaled nitric oxide for the postoperative management of pulmonary hypertension in infants and children with congenital heart disease. *Cochrane Database Syst Rev*. 2014 Jul 3;(7):CD005055.
- Canadian Pediatric Society (CPS), Fetus and Newborn Committee. Practice point. Inhaled nitric oxide use in newborns. January 1, 2020. Available at: <http://www.cps.ca/documents/position/Inhaled-nitric-oxide-use-in-newborns>. Accessed January 19, 2021.
- Clark RH, Kueser TJ, Walker MW, et al. Low-dose nitric oxide therapy for persistent pulmonary hypertension of the newborn. Clinical Inhaled Nitric Oxide Research Group. *N Engl J Med* 2000;342(7):469-74.
- Cole FS, Alleyne C, Barks JD, et al. NIH Consensus Development Conference statement: inhaled nitric-oxide therapy for premature infants. *Pediatrics*. 2011 Feb;127(2):363-9.
- DiBlasi RM, Myers TR, Hess DR. Evidence-based clinical practice guideline: inhaled nitric oxide for neonates with acute hypoxic respiratory failure. *Respir Care*. 2010 Dec;55(12):1717-45.

Dixon F, Ziegler DS, Bajuk B, et al. Treatment with nitric oxide in the neonatal intensive care unit is associated with increased risk of childhood cancer. *Acta Paediatr.* 2018 Dec;107(12):2092-2098.

Greenough, A., Decobert, F., Field D, et al. Inhaled nitric oxide (iNO) for preventing prematurity-related bronchopulmonary dysplasia (BPD): 7-year follow-up of the European Union Nitric Oxide (EUNO) trial. *J Perinat Med.* 2020 Sep 7:/j/jpme.ahead-of-print/jpm-2020-0164/jpm-2020-0164.xml.

Hasan SU, Potenziano J, Konduri GG, et al.; Newborns Treated With Nitric Oxide (NEWNO) Trial Group. Effect of inhaled nitric oxide on survival without bronchopulmonary dysplasia in preterm infants: a randomized clinical trial. *JAMA Pediatr.* 2017 Nov 1;171(11):1081-1089.

Hayes, Inc. Hayes Directory Review of Reviews. Inhaled nitric oxide for the treatment of respiratory failure in preterm newborns. Lansdale, Pa: Hayes, Inc.; November 2018.

Hilgendorff A, Apitz C, Bonnet D, et al. Pulmonary hypertension associated with acute or chronic lung diseases in the preterm and term neonate and infant. The European Paediatric Pulmonary Vascular Disease Network, endorsed by ISHLT and DGPK. *Heart.* 2016 May;102 Suppl 2:ii49-56.

Kumar P; Committee on Fetus and Newborn; American Academy of Pediatrics. Use of inhaled nitric oxide in preterm infants. *Pediatrics.* 2014 Jan;133(1):164-70.

Lawrence KM, Monos S, Adams, S, et al. Inhaled nitric oxide is associated with improved oxygenation in a subpopulation of infants with congenital diaphragmatic hernia and pulmonary hypertension. *J Pediatr.* 2020 Apr; 219:167-172.

McLaughlin VV, Archer SL, Badesch DB, et al.; American College of Cardiology Foundation Task Force on Expert Consensus Documents; American Heart Association; American College of Chest Physicians; American Thoracic Society, Inc; Pulmonary Hypertension Association. ACCF/AHA 2009 expert consensus document on pulmonary hypertension a report of the American College of Cardiology Foundation Task Force on Expert Consensus Documents and the American Heart Association developed in collaboration with the American College of Chest Physicians; American Thoracic Society, Inc.; and the Pulmonary Hypertension Association. *J Am Coll Cardiol.* 2009 Apr 28;53(17):1573-619.

Neonatal Inhaled Nitric Oxide Study Group (NINOS). Inhaled nitric oxide and hypoxic respiratory failure in infants with congenital diaphragmatic hernia. *Pediatrics* 1997;99(6):838-45.

Puligandla PS, Grabowski J, Austin M, et al. Management of congenital diaphragmatic hernia: A systematic review from the APSA outcomes and evidence based practice committee. *J Pediatr Surg.* 2015 Nov;50(11):1958-70.

Wang X, Li B, Ma Y, et al. Effect of NO inhalation on ECMO use rate and mortality in infants born at or near term with respiratory failure. *Medicine (Baltimore).* 2019 Oct;98(41):e17139.

Wu HW, Li ZG, Liu G, et al. Effect of nitric oxide inhalation for the treatment of neonatal pulmonary hypertension. *Eur Rev Med Pharmacol Sci.* 2016 Nov;20(21):4607-4611.

## Guideline History/Revision Information

Date	Summary of Changes
03/01/2021	<b>Supporting Information</b> <ul style="list-style-type: none"><li>Updated <i>Clinical Evidence</i> and <i>References</i> sections to reflect the most current information</li><li>Archived previous policy version MMG169.A</li></ul>

## Instructions for Use

This Medical Management Guideline provides assistance in interpreting UnitedHealthcare standard benefit plans. When deciding coverage, the member specific benefit plan document must be referenced as the terms of the member specific benefit plan may differ from the standard plan. In the event of a conflict, the member specific benefit plan document governs. Before using this guideline, please check the member specific benefit plan document and any applicable federal or state mandates. UnitedHealthcare reserves the right to modify its Policies and Guidelines as necessary. This Medical Management Guideline is provided for informational purposes. It does not constitute medical advice.

UnitedHealthcare may also use tools developed by third parties, such as the MCG™ Care Guidelines, to assist us in administering health benefits. UnitedHealthcare West Medical Management Guidelines are intended to be used in connection



with the independent professional medical judgment of a qualified health care provider and do not constitute the practice of medicine or medical advice.

Member benefit coverage and limitations may vary based on the member's benefit plan Health Plan coverage provided by or through UnitedHealthcare of California, UnitedHealthcare Benefits Plan of California, UnitedHealthcare of Oklahoma, Inc., UnitedHealthcare of Oregon, Inc., UnitedHealthcare Benefits of Texas, Inc., or UnitedHealthcare of Washington, Inc.