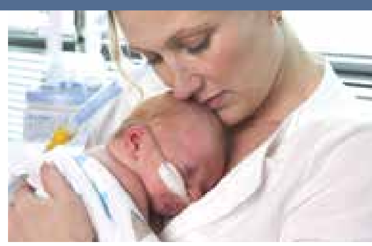
THERAPY OVERVIEW

Nurturing Life

The F&P Infant Respiratory Care Continuum™



Fisher&Paykel HEALTHCARE

The delicate new life of an infant can sometimes need help on the journey from hospital to home.

At Fisher & Paykel Healthcare, our goal is to provide caregivers with a **continuum** of humidified respiratory care solutions for every step of this journey.

Each step is focused on protecting compromised airways, fostering developmental care and optimizing the infant's outcomes, safely and efficiently. Critical to achieving these optimal outcomes is the delivery of **humidity** which emulates the natural balance of a healthy respiratory system.

In maintaining this natural state of physiological harmony, the infant can then channel its precious energy into vital growth and development.

Across this respiratory care continuum,
Fisher & Paykel Healthcare has developed a family of therapy solutions specifically designed to **nurture life.**

About Optimal Humidity

Humidification is central to the F&P Infant Respiratory Care Continuum. Our continuum delivers a level of humidity appropriate for the airway that is designed to match the body's own natural, balanced humidification to ensure the most effective and comfortable delivery of care.

OPTIMAL HUMIDITY

37 °C, 44 mg/L, 100% Relative Humidity

During normal inspiration, the airway conditions inspired gases with heat and humidity to body temperature, 100% Relative Humidity with 44 mg/L of Absolute Humidity. The lungs rely on these optimal states to maintain the physiological balance of heat and moisture necessary for optimized airway defense and gas exchange while maintaining patient comfort.

3 Key Benefits of Humidification

1. Assisting natural defence mechanisms in the airway
2. Promoting efficient gas exchange and ventilation
3. Increasing patient comfort and tolerance to treatment

A Quick Guide to Humidity

Humidity is a measure of the water vapor that is held in a gas.

1. Absolute Humidity

A measure of the total mass of water vapor that is contained in a given volume of gas.

2. Relative Humidity

A comparison of how much water vapor is contained in a gas compared with the maximum amount it can hold.

3. Temperature Affects Humidity

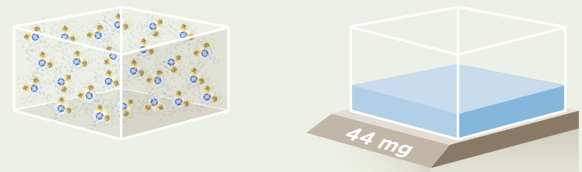
A warm gas can hold more water vapor than a cold gas.

4. Size Does Matter

It is physically impossible for water vapor to transport bacteria and viruses.

01 ABSOLUTE HUMIDITY (AH)

This represents the total amount of water vapor in a given volume of gas in which it is contained. Absolute Humidity is measured as mass divided by volume of gas (mg/L).



If the water held in a liter of gas were condensed out and weighed in milligrams, the Absolute Humidity of the gas would be measured in milligrams of water per liter of gas.

02 RELATIVE HUMIDITY (RH)

This takes into account the water contained in the gas, compared with how much water it can hold before the vapor condenses out to liquid water. Relative Humidity is measured as a percentage.

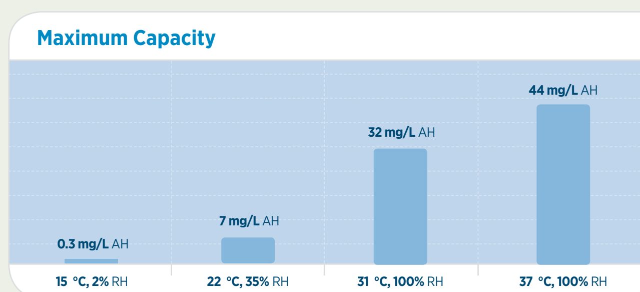
25% RH | **100%** RH

25% RH - If a liter of gas holds a maximum 44 mg of water vapor, it will be a quarter-full and contain only 11 mg of water vapor. So its Relative Humidity (RH) is 11 mg / 44 mg or 25% RH.

100% RH - If the same volume of gas holds 44 mg of water vapor, it is full or saturated with water vapor. So its Relative Humidity is 44 mg / 44 mg or 100% RH.

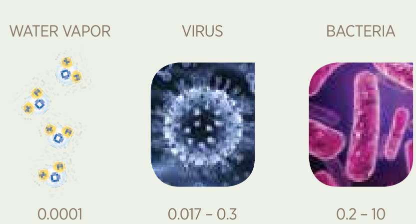
03 MAXIMUM CAPACITY

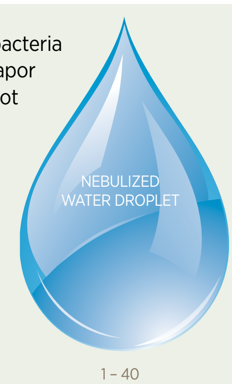
The quantity of water vapor that gas can hold increases with the temperature of the gas. A warm gas can hold more water vapor than a cold gas.



04 PARTICLE SIZE

Water droplets (aerosols) are large enough that bacteria and viruses can be transported by them. Water vapor molecules are much smaller and pathogens can not attach themselves to be transported.





The Infant's Airway

An infant's respiratory system is a fragile mechanism reliant on humidity. It is necessary, therefore, to understand the physiological balance that humidity provides.

TWO MAIN LUNG FUNCTIONS

Airway Defense

The **primary** defense mechanisms of the airway are reflexes such as sneezing, coughing and gagging, and natural filtration provided by nasal hairs and the upper airway. In an infant's airway, these mechanisms are underdeveloped and are either under-utilized or not utilized at all.

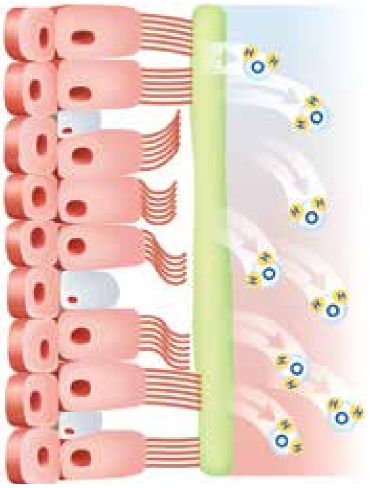
The **secondary** line of defense is the mucociliary transport system which traps and neutralizes inhaled contaminants (in mucus) and transports them up and out of the airway. This keeps the lungs free from infection-causing pathogens. The efficiency of this mechanism is heavily dependent upon the age of the infant and the temperature and humidity of inspired gases.

Gas Exchange

Air-flow to the alveoli is necessary for gas exchange to occur. The natural addition of heat and moisture as gas travels down the airway on inspiration assists with maintaining clear, open airways to allow unobstructed air-flow. This is achieved by optimizing mucociliary clearance, improving lung compliance and reducing bronchoconstriction associated with airway cooling.

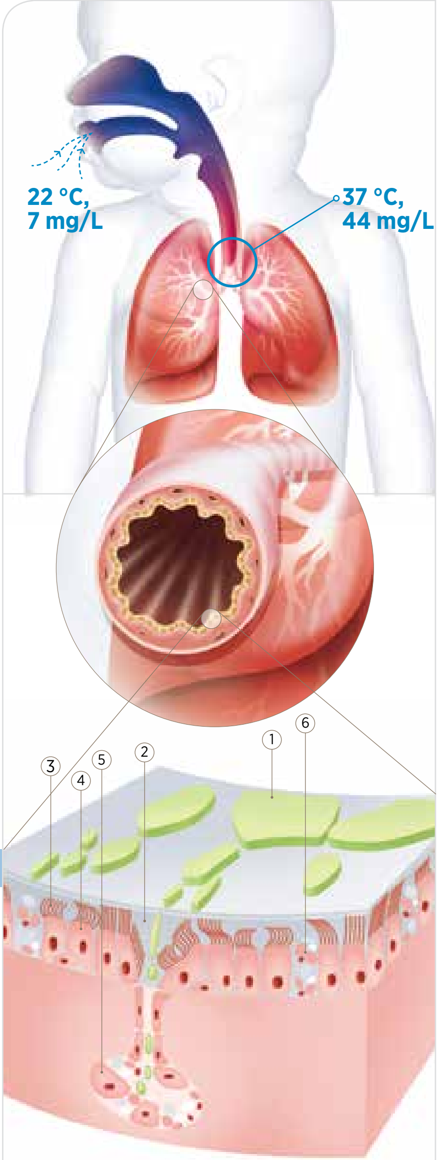
An infant's airway produces proportionally more mucus compared to the level they will produce later in life, but does not have the same ability to clear it away. This can influence the maintenance of an open airway and inhibit gas exchange.

THE MUCOCILIARY TRANSPORT SYSTEM



Millions of cilia (hair-like structures) lining the epithelium of the upper and lower airways beat through an aqueous layer, moving mucus – and with it contaminants – out of the airway. The efficiency of this defense mechanism is critical in reducing the incidence of respiratory infection while optimizing gas exchange. This is reliant on the coordination and beat frequency of the cilia, and the viscosity of the mucus (which in turn is heavily influenced by the level of humidity to which the mucosa is exposed).

The airway surface contributes heat and moisture to inspired gas until it reaches 37 °C, 44 mg/L. The lower the humidity of the inspired gas, the further it needs to travel down the airway before this temperature and humidity are reached.



Mucociliary Transport System

1 Mucus

2 Aqueous layer

3 Cilia

4 Epithelium cell layer

5 Submucosal gland

6 Goblet cell

Adapted from Williams et al. (1996)[1]

The Compromised Airway of an Infant

The mucociliary transport system of an infant is inherently compromised. The cilia are often too short and uncoordinated to reach into the mucus layer effectively. Providing low-humidity gas with respiratory support can severely compromise mucociliary clearance and the underdeveloped infant even further.

1. Medical gases

These gases are cold and extremely dry. Their use in respiratory medicine often means that low-humidity gases are delivered to infants. The influence of this can be significant. The table below highlights various forms of humidified gas that can be delivered to infants in hospital.

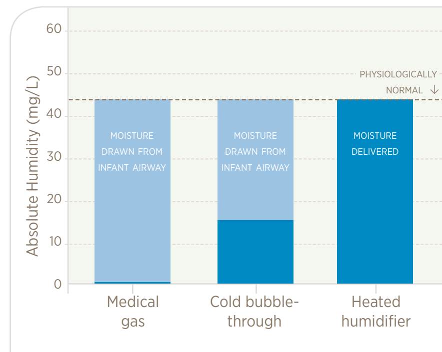
2. A bypassed airway

Endotracheal or tracheostomy tubes bypass the upper airway where the majority of heat and moisture is normally added during inspiration. In this process, the filtering mechanisms of the upper airway are also bypassed.

3. Inspiratory flows

Even though medical gas flow rates may be classed as "low", they may still make up a significant proportion or exceed the infant's minute volume, drawing excessive heat and moisture from the airway mucosa.

	TEMPERATURE	ABSOLUTE HUMIDITY
MEDICAL GAS (PIPED OXYGEN)	15 °C	0.3
COLD BUBBLE-THROUGH HUMIDIFIER	Ambient	16.0 mg/L
HEATED HUMIDIFIER	37 °C	44.0 mg/L



The graph above highlights the levels of humidity able to be delivered during various respiratory interventions, against what is physiologically normal (37 °C, 44 mg/L) for the lungs. The deficit must be made up by the infant's airway – requiring significant consumption of precious energy reserves.

A Threat to Energy Reserves

Developing infants need energy for growth and development. The depletion of heat and moisture from the airway can negatively impact these limited energy reserves through:

Increased Risk of Infection

Low-humidity gases increase the risk of infection by placing strain on the mucociliary transport system, reducing its efficiency and the expulsion of infection-causing contaminants.

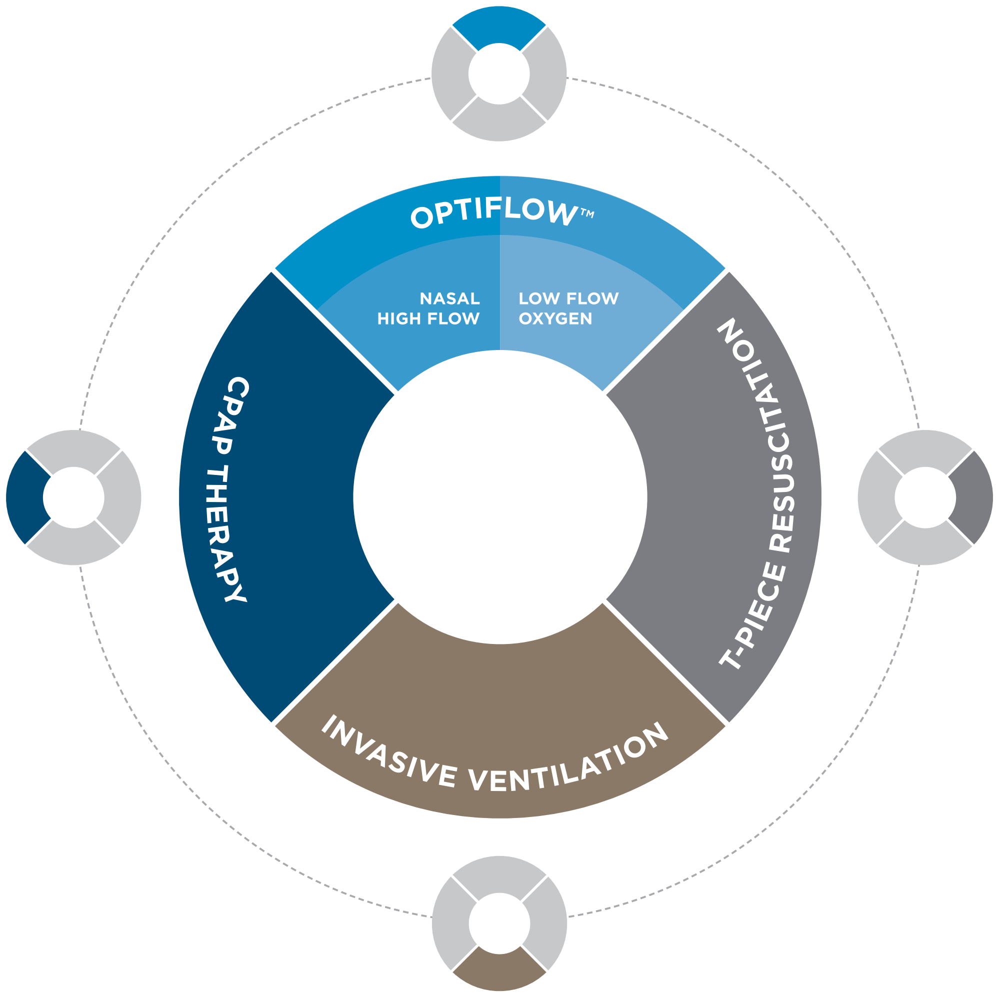
Reduced Respiratory Mechanics

The work of breathing can significantly increase when the airway lumen is reduced through intubation, secretion build-up, bronchoconstriction and poor lung compliance.

Evaporative Losses

When inadequate levels of humidity are inhaled, water vapor is drawn from the airway mucosa until the inspired gas has reached 37 °C, 44 mg/L. The energy cost to the infant for each gram of water removed from the mucosa is 0.58 kCal (2.4 kJ).[2]

Nurturing Life



F&P INFANT RESPIRATORY CARE CONTINUUM™

Precious new life deserves the best possible start. From the infant's first breath, the F&P Infant Respiratory Care Continuum facilitates the transition from immature lung function to respiratory independence.

At every point of the care continuum, humidified solutions help to emulate the natural physiological balance in healthy mature lungs. As an infant's needs change, so does the configuration of the therapy system. As a result caregivers can nurture life, confident they are using the best therapy solutions, delivered in the most efficient way.

OPTIMAL HUMIDITY

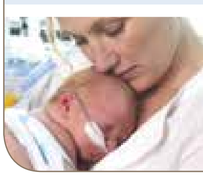
37 °C, 44 mg/L, 100% Relative Humidity

delivered by...

T-PIECE RESUSCITATION

Safe, Consistent, Optimal Resuscitation

In the event the infant fails to take that first vital breath, Infant T-Piece Resuscitation helps facilitate optimum oxygenation while protecting the lungs from injury.



OPTIFLOW™

NASAL HIGH FLOW - Comfortable, Effective Oxygen Delivery

The combination of Optimal Humidity and nasal cannula provides comfortable and effective delivery of greater oxygen flows than previously possible.

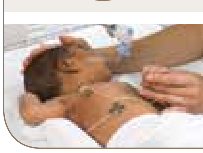
LOW-FLOW OXYGEN - Tender Care at Low Flows

The addition of Optimal Humidity with traditional low-flow oxygen therapy can improve the comfort of the infant while optimizing mucociliary clearance.

CPAP THERAPY

Maximize Lung Protection and Breathing Support

CPAP enhances breathing support and protects the developing lungs.



INVASIVE VENTILATION

Optimize Airway Defense and Ventilation

Invasive ventilation with Optimal Humidity is the best solution for supporting airway defense functions and ventilation.

Therapy Solutions Overview

Restoring Natural Balance to Nurture Life

The infant airway does not reach physiological maturity until two years of age. Respiratory interventions without humidity impede the infant's development and exacerbate the associated risks. An immature airway is reliant on a delicate balance of temperature and humidity.

See the following therapy pages to learn more about the benefits of humidified therapies, at every step of the respiratory care continuum.

T-Piece Resuscitation

Safe, consistent and optimal resuscitation

T-PIECE RESUSCITATION TO NURTURE LIFE

Infant T-Piece Resuscitation is designed to provide safe, consistent and optimal resuscitation for infants. It facilitates optimum oxygenation while protecting the lungs from injury.

Optimal resuscitation is the application of positive pressure to inflate the lungs and achieve maximum alveolar recruitment without causing further damage (and while establishing functional residual capacity (FRC)).

OPTIMAL HUMIDITY

Optimal resuscitation can make use of Optimal Humidity (37 °C, 44 mg/L) by conditioning the gas flow to the natural level of humidity. This restores natural balance and provides a level of humidity found normally in the airways.

Protect with Controlled Pressures

Infant T-Piece Resuscitation has the benefit of providing controlled pressures to help prevent lung over-distension that can result in further injury, such as barotrauma, which could lead to bronchopulmonary dysplasia (BPD). Such pressures are defined as controlled and precise peak inspiratory pressure (PIP) along with consistent and precise positive end expiratory pressure (PEEP).[1] These controlled pressures are delivered more accurately when compared with the use of a self-inflating bag.[2 3]

Furthermore, sustained inflation pressures can be delivered with Infant T-Piece Resuscitation. Sustained inflation pressures have been shown to establish lung volume in term infants requiring resuscitation.[4]

An International Benchmark

All major resuscitation guidelines from around the world recommend the use of Infant T-Piece Resuscitation; this includes the International Liaison Committee on Resuscitation (ILCOR)[5] and American Heart Association's (AHA)/Neonatal Resuscitation Program (NRP)[6].

BENEFITS OF INFANT T-PIECE RESUSCITATION

INFANT	CLINICIAN
Safely inflates infant's lungs with controlled pressures	The operators; experience, training, concentration and fatigue level do not affect the pressures delivered. This is highly reassuring for the clinician[2 7]
Oxygen concentrations from 21 to 100% can be delivered[8]	PEEP can be used during surfactant delivery
Humidified resuscitation helps reduce heat and moisture loss in the airways	Can provide consistent PEEP during transport or ventilator circuit change
Consistent PEEP can improve lung compliance	Initial sustained inflations can be delivered to establish lung volume
	Can deliver an ideal Inspiratory versus Expiratory ratio – allows for better gas exchange

PATIENT NEEDS AND OPTIMAL OUTCOMES

An infant requiring resuscitation has the essential need of oxygenation; however, factors such as prematurity or diseases such as respiratory distress syndrome (RDS) can make its requirements more complex. There is the need to protect an underdeveloped and/or compromised respiratory system.

To provide safe, consistent and optimal resuscitation, the infant requires six factors (all of which are resolved by Infant T-Piece Resuscitation):

1. Safe, controlled PIP

PIP is the maximum inspiratory pressure. The main objective in delivering PIP is to inflate and recruit alveoli to achieve gas exchange using the lowest possible pressure. The PIP level may vary from infant to infant depending on factors such as gestational age, body size and lung condition.

Safe, controlled PIP can be consistently delivered by Infant T-Piece Resuscitation as shown in the graph opposite. The square waveform has the advantage of longer time at controlled peak pressure that may open up the lungs, allowing adequate time for gas exchange to occur.

2. Consistent, precise PEEP

PEEP is the pressure in the lungs at the end of expiration. Consistent PEEP allows gas to remain inside the lungs after expiration and helps to establish FRC. The establishment of FRC with Infant T-Piece Resuscitation has been shown to be an effective strategy to help protect the immature infant's lungs.[1]

3. Ideal breath rate

A rate of 40 to 60 breaths per minute is suggested by the NRP, which can be delivered with a T-Piece resuscitator.

4. Delivery of required O_2 (21-100%)

Infant T-Piece Resuscitation can deliver 21 to 100% oxygen during resuscitation.[8]

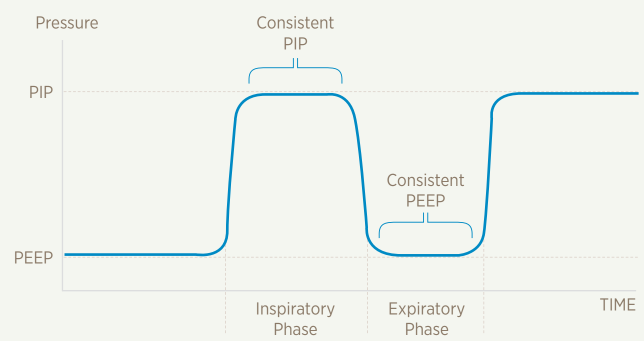
The hospital protocol or guidelines will indicate appropriate requirements.

5. Ideal seal

Achieving an ideal seal for resuscitation is essential as too much leak will result in insufficient ventilation. T-Piece resuscitation allows the clinician to achieve proper positioning by using one hand for delivering breaths and the other to hold the mask in place.

6. Surfactant with PEEP

Surfactant plays a major role in decreasing the surface tension in the lungs and reducing the tendency of the lungs to collapse. T-Piece resuscitation allows the delivery of surfactant while providing PEEP.



INFANT T-PIECE RESUSCITATION WITH OPTIMAL HUMIDITY

OPTIMAL HUMIDITY

Infant T-Piece Resuscitation with Optimal Humidity (37 °C, 44 mg/L) is designed to deliver humidified gas to an infant during resuscitation. Optimal Humidity (heated and humidified gas) helps to protect the pulmonary epithelium and reduce postnatal decrease in temperature[9] and moisture loss (especially during prolonged resuscitation).

Conditioning cold, dry gas to body temperature and saturating with water vapor can help reduce the risk of an inflammatory response occurring in the infant's airway caused by drying.[10]

Nasal High Flow

Comfortable, effective oxygen delivery

NASAL HIGH FLOW TO NURTURE LIFE

Nasal High Flow (NHF™) is a comfortable and effective means of delivering oxygen to infants in respiratory distress.[1] It provides a revolutionary bridge between low-flow oxygen therapy and continuous positive airway pressure (CPAP) therapy and may reduce the requirement for CPAP and intubation in some clinical scenarios.[2 3 4]

NHF efficiently delivers oxygen by employing a lighter, less bulky nasal cannula system (compared with that used in other therapies which often require excess equipment on and around the infant's face). This can enable easier parental interaction, "kangaroo care" and feeding, while improving the comfort of the infant.[5]

OPTIMAL HUMIDITY

Traditionally, unhumidified oxygen has been limited to 2 to 4 L/min[6 5] because of issues with tolerance, and upper airway trauma.[7 8] Supplementing the gas flow with Optimal Humidity, 37 °C / 44 mg/L, limits these problems, allowing the delivery of higher gas flows.

PATIENT NEEDS

Comfort

Any respiratory therapy with a spontaneously breathing infant is difficult to provide effectively if the infant struggles to tolerate it. Discomfort and intolerance can result in the need for increased sedation and escalation of respiratory support. Infants on oxygen therapy can often be more active than those on higher levels of respiratory assistance, increasing the need for a comfortable, well-tolerated therapy. NHF has been shown to be a comfortable and well-tolerated treatment option for these infants.[5 2]

Efficient Oxygen Delivery

With traditional oxygen therapy it is generally understood that the amount of oxygen being delivered to an infant is difficult to control and varies depending on the changing inspiratory flow of the infant (AARC guidelines).[6] The introduction of NHF has meant that clinicians now have the ability to deliver a more accurate fraction of inspired oxygen (FiO_2) (Sim et al.[9] AARC guidelines[6]).

Reduced Work of Breathing

Treatment of infants in respiratory distress is often aimed at reducing their work of breathing. This can be provided through the delivery of CPAP. However, interfaces for this type of therapy can be bulky and difficult to apply. Inherently with NHF, a variable level of positive airway pressure is provided with a simple nasal cannula.[8 10]

OPTIMAL OUTCOMES

Clinicians generally aim at providing effective respiratory support to infants using the least invasive, most safe and gentle means available. NHF strives to provide clinicians with a comfortable and effective way of delivering respiratory support to infants:

Comfortable Oxygen Delivery

A comfortable, well-tolerated oxygen flow is essential when continuous, uninterrupted oxygen delivery is required. NHF combines a low-profile nasal cannula with Optimal Humidity to improve the comfort and tolerance of infants.

Effective Oxygen Delivery

Control and flexibility of oxygen delivery is vital when caring for a patient population that is so vulnerable to oxygen over-exposure. NHF is a comfortable and effective form of oxygen therapy, delivering a wide range of flows and oxygen concentrations.

This means that, unlike low-flow oxygen therapy, the infant's prescribed FiO_2 can be maintained regardless of fluctuations in their inspiratory demand if the delivered flow meets or exceeds this demand.[1]

It is understood that there are two factors contributing to this:

1. Dilution of the delivered flow is minimized as the infant doesn't need to entrain room air to meet its inspiratory demand.
2. A reservoir of fresh, oxygen-enriched gas is created in the upper airway as a result of the higher gas flow that is available for each and every breath.

Easier Work of Breathing

Similar pressures and work-of-breathing parameters have been found when directly comparing the delivery of NHF to CPAP.[11] The level of pressure generated by NHF is dependent on a number of factors including flow rate, structure of the nasal cannula, and the weight and nasal anatomy of the infant.[10 12]

It is important to note that the amount of pressure provided with NHF is variable. If a set pressure is indicated, a pressure control system should be utilized.

Key patient populations where NHF has been shown to be an effective treatment option:

- Respiratory distress[5 10 13]
- Bronchiolitis[2]
- Apnea of prematurity[10 11 12]
- Chronic lung disease[10 11]
- Infants susceptible to nasal trauma, maintaining mucosal integrity through humidification[8]
- Infants weaning from invasive ventilation and CPAP[3 4 14]

BENEFITS OF NHF WITH OPTIMAL HUMIDITY

INFANT	CLINICIAN
More comfortable and tolerable than other respiratory therapies	May reduce the requirement for CPAP[4]
Receives a more accurate level of oxygen	May lessen the need for intubation[2 3]
Reduces the work of breathing	Easy to set up and maintain
Can enjoy greater interaction with parents and clinicians (assisting developmental care)	More control and flexibility with FiO_2 delivery
More likely to receive an uninterrupted oxygen flow	Easier holding of the infant
Less risk of upper airway trauma	Sedation may be reduced due to the infant being more comfortable
Easier feeding	May shorten the length of stay

Low-Flow Oxygen

Tender care at low flows

LOW-FLOW THERAPY TO NURTURE LIFE

Delivery of oxygen with a nasal cannula has traditionally been poorly humidified. Because even low flows can make up most of an infant's minute volume required, use of unhumidified oxygen can result in significant drying, discomfort and complications, particularly if used for longer periods.

OPTIMAL HUMIDITY

Conditioning the gas to be physiologically normal with Optimal Humidity (37 °C, 44 mg/L) protects the developing airway from drying, helping to prevent many of the ill-effects traditionally associated with this type of therapy.

PATIENT NEEDS

Infants requiring oxygen therapy may also have secretion problems. Secretion clearance issues, such as with bronchiolitis, can lead to pooling of mucus in the lungs – creating an environment where infection-causing pathogens can multiply. The delivery of Optimal Humidity assists in maintaining this mucociliary clearance system, helping to fight off respiratory infection.

OPTIMAL OUTCOMES

Drying from the use of oxygen can stifle mucociliary clearance, cause damage to the delicate mucosa in the developing airway and, as most clinicians will be aware, result in an unsettled infant. Optimal Humidity can reduce these complications and also lessen the time spent attending to an unsettled infant.

Reduced Complications and Attendance Time

As well as diverting energy away from the developmental process for the infant, attending to these side effects can translate to increased attendance time for the caregiver. The delivery of physiologically normal gas, 37 °C / 44 mg/L, prevents drying of the airway, protecting it from these complications and reducing associated attendance time.

Maintained Mucociliary Clearance and Clear, Open Airways

Optimal Humidity emulates the balance of temperature and humidity that occurs in healthy lungs. This can be particularly important for patients with secretion problems. By delivering Optimal Humidity, drying of the airway is reduced, and the function of the mucociliary transport system is maintained. As a result secretions are cleared more effectively and the risk of respiratory infection is reduced.

BENEFITS OF LOW-FLOW THERAPY WITH OPTIMAL HUMIDITY	
INFANT	CLINICIAN
Reduces nasal and mucosal damage	Reduces attendance time refitting the cannula
Minimizes heat and moisture loss	Improves continuity of treatment; better likelihood of therapy success
Secretions in the airway remain mobile	A versatile system reduces the need to change equipment as the patient requires more or less support
Improves continuity of treatment; better likelihood of therapy success	

CPAP Therapy

Maximize lung protection and breathing support

CPAP THERAPY TO NURTURE LIFE

Continuous positive airway pressure (CPAP) nurtures and supports infant breathing by providing respiratory support throughout the respiratory cycle. The application of CPAP maintains the infant's functional residual capacity by helping to prevent airway closure. CPAP promotes gas exchange in the alveoli,[1] which acts to enhance airway patency,[2] improve lung volume recruitment[2] and maintain infant energy reserves, without the complications associated with endotracheal intubation.[3]

OPTIMAL HUMIDITY

Optimal Humidity (37 °C, 44 mg/L) with CPAP is vital to support an infant's breathing and protect its developing lungs. Humidifying its medical gases ensures minimal exertion is required for breathing which in turn allows the infant to conserve precious energy.[4]

Conditioning inspired gas is critical to safeguard the infant's lungs. Optimal Humidity maintains the natural balance of heat and moisture in the infant's airway and maintains mucociliary function so that mucus and contaminating particles, including pathogens, can be cleared from the airway.[5 6] This helps to prevent blockage of the airways by mucus[7] and reduce the infection rate.

The American Association of Respiratory Care (AARC) guidelines recommend the use of heated humidification with infant nasal CPAP.

PATIENT NEEDS

There are a number of problems associated with premature lungs, such as weak, compliant chest wall, collapsible airways, atelectasis, uneven alveolar ventilation and increased work of breathing.

A normal, healthy infant has the ability to heat and humidify inspired gases through its airway. In a pre-term or sick infant, however, this process can harm the lungs and will reduce its energy reserves.[4]

Providing breathing support that will maintain the natural balance of heat and moisture in the airways will help to prevent further lung damage as the lungs continue to mature.[1] Some of the factors associated with CPAP that will benefit from Optimal Humidity include:

Rapid Respiratory Rate

Infants have a rapid breathing rate which is exacerbated by respiratory distress. Their small lung capacity means that they are unable to breathe deeply. A more rapid breathing rate requires increased effort from the infant and increases the heat lost from the airway.[9]

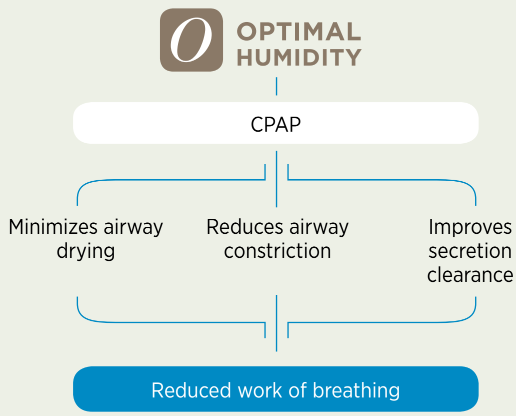
Fluid Depletion

Infants receiving CPAP therapy can become dehydrated due to respiratory distress. If the infant is predisposed to reduced secretion removal as a result of an underlying respiratory disorder, the drying of the airway can promote the retention of secretions which can cause airway blockage.[10]

Oral Breathing

Older infants tend to breathe through their mouth as there is less resistance. Oral breathing humidifies the gas less than that of nasal breathing, which means the air in the upper airways is cooler and drier than air breathed through the nose.[11]

OPTIMAL OUTCOMES



Optimal Humidity with CPAP supports infant breathing by reducing the work of breathing. This protects the developing lungs to optimize outcomes for the infant by:

Minimizing Airway Drying

Delivering Optimal Humidity with CPAP ensures that the airway remains moist and may prevent inflammation of the airway caused by drying of the mucosa.[12]

Reducing Airway Constriction

Dehydration of the airway can result in contraction of the airways or broncho-constriction in some infants. Heated humidification may prevent this from occurring.[13]

Improving Secretion Clearance

Optimal Humidity helps protect the lungs by restoring fluid levels in the mucociliary transport system, which improves secretion clearance and maintains the work of breathing at normal levels. This prevents the drying and accumulation of mucus and secretions, helping to keep the airway clear and open and to keep the work of breathing at normal levels.[14]

These effects combine to reduce the work of breathing

The application of medical gases without humidity may cause airway dehydration, making mucus secretions viscous so that they build up in the airway. This may reduce the airway diameter and increase the resistance to flow.[7] We may also see an increase in the work of breathing for the infant,[15] heightening the risk of hypoxemia.[4] This could result in the infant having to utilize further energy reserves. Heated humidification during CPAP provides breathing support by reducing airway resistance of the nasal passages,[16] creating an increased tidal volume[17] and pressure delivery to the lower airways.[18]

BENEFITS OF CPAP WITH OPTIMAL HUMIDITY

INFANT	CLINICIAN
Minimizes airway drying and inflammation	Increases clinician confidence in CPAP
Reduces congestion and bronchoconstriction	Reduces nasal cleaning and maintenance
Improves secretion clearance	Can lessen the need for intubation[19]
Better work of breathing	Reduces length of stay in hospital[21]
Improves ventilation	

BUBBLE CPAP WITH OPTIMAL HUMIDITY

OPTIMAL HUMIDITY

Bubble CPAP is a unique form of CPAP therapy. Infants on bubble CPAP have been reported to have chest wall vibrations similar to high frequency ventilation (HFV).[2] There is some evidence to suggest that the small vibrations it produces in the infant's chest (at a frequency of 15 to 30 Hz) may speed up gas exchange through facilitated diffusion and decrease both the respiratory rate and minute ventilation, without increasing partial pressure of CO_2.[20] Infants on bubble CPAP were noted to have reduced delivery room intubations, decreased days on mechanical ventilation, lower postnatal steroid use, increased postnatal weight gain and maintained the level of inherent complications.[19 21]

The application of humidity with bubble CPAP enhances the effectiveness of the therapy, resulting in better respiratory outcomes. Optimal Humidity maintains the natural balance in the infant's airways. Gas exchange is optimized and the delicate infant lungs are protected from further damage. As the infant's lungs continue to mature after birth, the therapy will facilitate the normal development process until the infant can breathe on its own.

With the combined effects of Optimal Humidity and natural pressure oscillations, bubble CPAP provides a protective, safe and effective method of respiratory support to spontaneously breathing neonates.

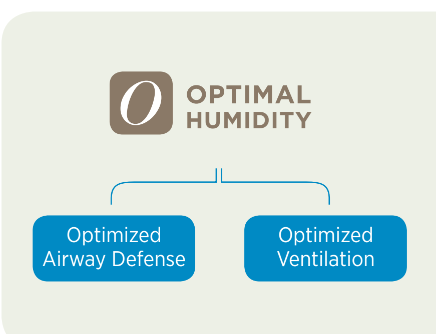
Invasive Ventilation

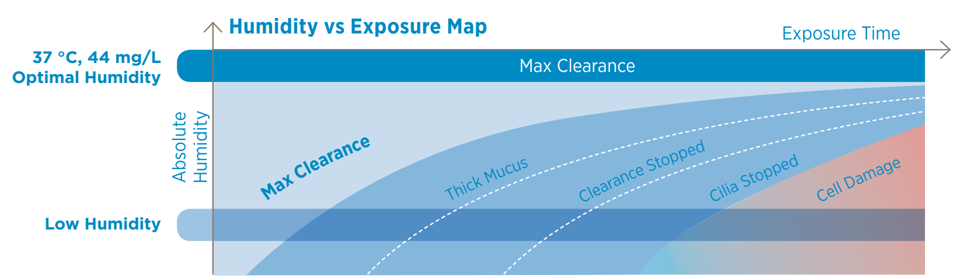
Optimal Humidity optimizes airway defense and ventilation

INVASIVE VENTILATION TO NURTURE LIFE

The delivery of Optimal Humidity for an intubated infant is crucial for growth and development. Inspired gases conditioned to body temperature, 37 °C, and fully saturated with 44 mg/L of water vapor, will mimic the natural physiological conditioning of the airways. This optimal level of humidity will optimize the infant's airway defense, airway patency, lung function and the work of breathing.

OPTIMAL HUMIDITY Optimal Humidity (37 °C, 44 mg/L) is the level of humidity at which mucociliary function is preserved. Gas delivered at optimal conditions will prevent the depletion of moisture in the airway and maintain mucus clearance. If the airway mucosa is exposed to humidity levels below Optimal Humidity, the mucociliary transport system will become compromised. As shown in the graph below, prolonged exposure to low humidity leads to cell death. The lower the level of humidity delivered and the longer the duration, the quicker dysfunction will occur.[1]





Humidity vs exposure map, illustrating how mucosal function varies with inspired humidity over time. Adapted from Williams et al. (1996)[1]

PATIENT NEEDS

Airway Defense

An endotracheal tube not only bypasses the body's natural humidification processes but also inhibits mechanical clearance such as cough, gag, sneeze and particle filtration. This leaves the mucociliary transport system as the airway's only remaining mechanical defense method. As this mucociliary system is already inefficient and the infant's immune system immature, the preservation of this transport system is vital.[2]

Ventilation

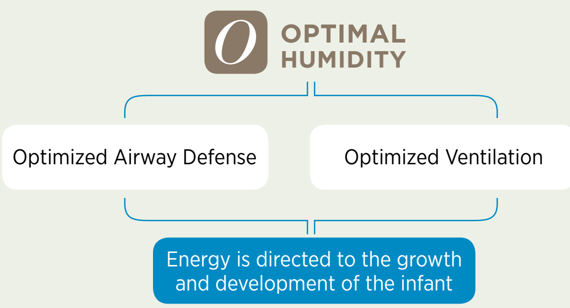
Clear Airways and Minimal Work of Breathing
Effective ventilation is critical for the intubated infant. Most importantly, a clear and unobstructed endotracheal tube allows for optimized patient ventilation. Infants produce proportionately more mucus for the size of their airways compared to the level they will produce later in life. Therefore, secretion clearance needs to be maintained to allow for clear and open airways enabling gas to pass from the endotracheal tube down to the alveoli. To maintain effective ventilation, the compliance and airway resistance of the lungs need to be preserved to reduce the infant's work of breathing.

Lung Function It is critical to prevent the occurrence of lung dysfunction. Avoidance of pneumorathoraces and extended periods of oxygen demand (e.g. chronic lung disease) will enable better outcomes for the infant.

Thermal Work of Breathing For each and every breath the volume of inspired gas needs to be conditioned to body temperature and full saturation (37 °C, 44 mg/L). A large proportion of the infant's energy is therefore used to condition these inspiratory gases.[3] It is important that the energy expended in gas conditioning is reduced so that the infant's limited energy reserves can instead be directed towards growth and development.

OPTIMAL OUTCOMES

Patient outcomes can be optimized with the delivery of Optimal Humidity. Optimal Humidity optimizes airway defense and ventilation. This is critical to allow the infant's limited energy reserves to be directed towards growth and development.



The delivery of Optimal Humidity provides gases that are at physiologically balanced conditions to that of the infant's airways. Optimal Humidity will:

Optimize Airway Defense

Efficient secretion clearance will increase pathogen removal and reduce sites for pathogen replication. The removal of pathogens will reduce the risk of infection.[4]

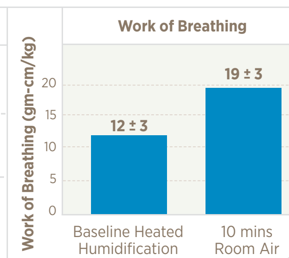
Optimize Ventilation

Clear Airways and Reduce Work of Breathing

Efficient secretion clearance through the delivery of Optimal Humidity will reduce the risk of endotracheal tube occlusions and the presence of secretions blocking off airways.[5] A lack of drying of the airways will also reduce the infant's lung compliance, resistance to flow (RTF), and work of breathing (WOB).[6] As shown in the graph below, just 10 minutes of room air (low humidity) delivered to the lungs via an endotracheal tube causes a significant increase in WOB.

The effect of 10 minutes of room air delivered to stable pre-term intubated infants (previously on humidification)

	Baseline	After	P Value
Compliance mL/cm H_2O/kg	1.12	0.94	P<0.005
RTF cm H_2O/L/kg	37	71	P<0.005
WOB gm-cm/kg	12	19	P<0.005



Adapted from Greenspan et al. (1991)[6]

Improve Lung Function

Lung function will improve with the delivery of Optimal Humidity. A decrease in humidity will increase the incidence of pneumothorax and the need for supplemental oxygen.[7]

Reduce Thermal Work of Breathing

If each breath is conditioned to Optimal Humidity then the infant does not need to expend energy to condition inspired gases. Energy can instead be conserved for growth and development.[3]

BENEFITS OF INVASIVE VENTILATION WITH OPTIMAL HUMIDITY

INFANT	CLINICIAN
Increases airway defense, reducing risk of infection[4]	Provides the best level of patient care
Increases patency of endotracheal tubes[5]	Can reduce the need for saline aerosol therapy and instillations
Increases sputum clearance[1]	Suctioning can become more effective
Prevents airway drying[1]	May reduce institutional costs through effective patient care
Increases lung compliance[6]	
Reduces lung resistance[6]	
Decreases work of breathing[6]	
Decreases lung dysfunction[7]	
Aids thermoregulation[3]	

Our Family of Solutions to Nurture Life

Fisher & Paykel Healthcare is committed to advancing our capabilities as a world leader in humidified therapy systems with a comprehensive family of solutions to nurture life.

At every point of the F&P Healthcare Infant Respiratory Care Continuum efficient, optimal care is delivered through the varied combination of a:

- Humidified care platform
- Delivery system
- Patient interface

Each therapy system is created to also nurture the developmental-care strategies of NICUs and support the infant's journey to natural balance – a state of physiological equilibrium found in mature, healthy lungs.

PLATFORM	MR850 Neopuff™	MR850 AIRVO™ 2*	MR850	MR850
DELIVERY SYSTEM	• T-Piece resuscitation system	• MR290 auto-fill humidification chamber • RT Series breathing circuits	• MR290 auto-fill humidification chamber • RT Series breathing circuits	• MR290 auto-fill humidification chamber • RT Series breathing circuits
PATIENT INTERFACES	• Resuscitation masks	• BC Series cannula • RT Series cannula • OPT31X Series F&P Optiflow™ Junior nasal cannula	• FlexiTrunk™ • Nasal prongs • Nasal mask	

** For use with OPT316 infant and OPT318 pediatric F&P Optiflow™ Junior nasal cannula.*

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