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Infant Key references

**THERAPY OVERVIEW**


**CLINICAL OUTCOMES**


**PHYSIOLOGICAL OUTCOMES**


High flow nasal cannula: recommendations for daily practice in pediatrics

AIM:
This review provides an overview of nasal high-flow (NHF) oxygen therapy and its use in pediatric patients based on current published literature.

DETAILS:
Use of NHF oxygen therapy in neonatal departments has increased steadily over the last decade, where it has gradually replaced continuous positive airway pressure (CPAP). Use in pediatric patients is also increasing, mostly in children with moderate bronchiolitis. NHF delivers heated and humidified respiratory gases at flow rates higher than a patient’s inspiratory flow, which has been shown to provide better oxygen delivery than low-flow oxygen therapy or a high-concentration oxygenation mask. The definition of “high flow” varies between clinical settings, with >2 L/min and >6 L/min generally considered as high flow in infants and children, respectively. Flow rates can be adjusted based on body weight (e.g. 2 L/kg/min). The idea is that the high flow of oxygen washes out end-expiratory oxygen-depleted gas, resulting in more oxygen inhalation in the next breath and less carbon dioxide rebreathing. This effect is more marked in children, whose extrathoracic deadspace is proportionally 2- to 3-times higher than that in adults. This is particularly the case in younger children, who have the most to gain from NHF in terms of improved oxygenation and carbon dioxide clearance.

Types of devices: NHF is delivered via a nasal cannula that needs to be fitted for the individual patient. It is suggested that the prong diameter should be about half the nostril diameter to allow for leakage and avoid excessive pressure. There are three types of gas generators currently available. The first uses an air/oxygen blender with a heated humidifier (Optiflow™ System, Fisher & Paykel Healthcare; Precision Flow™, Vapotherm; Comfort-Flo®, Teleflex). Another type of NHF generator uses a turbine plus a humidifier (AIRVO™2, Fisher & Paykel Healthcare) and does not require an external gas source. However, it cannot be used for neonates and takes longer to set up than other types. The third type is based on a CPAP or conventional ventilator with a NHF circuit connected to the humidifier. The associated heating and humidification of inspired gases during NHF improves patient comfort by reducing the sensation of respiratory distress and mouth dryness.

Pressure delivery: The maximum pharyngeal pressure generated during NHF is likely to be approximately 6 cmH₂O during expiration. Pressure is determined largely by the flow rate, but the fit of nasal prongs within the nostrils and whether or not the mouth is closed also play a role. There can be wide variations in delivered pressure both between patients and in the same individual over time.

Indications and initiation: There is a lack of data on NHF oxygen therapy in pediatric patients, and the most recent recommendations are based on observational data rather than clinical trial evidence. It appears that NHF is feasible in most of the patient groups that would otherwise be managed with noninvasive ventilation (NIV), and is often better tolerated. The most-studied pediatric indication is acute viral bronchiolitis, where use of NHF has been associated with a decreased intubation rate compared with historical controls, and has a failure rate similar to CPAP. Other potential uses for NHF oxygen therapy include weaning from invasive mechanical ventilation and possibly in patients with asthma.

The proportion of patients treated with NHF who go on to require intubation has been reported as 8–19%, or up to 30% when considering requirement for additional respiratory support in addition to intubation. So that patients can be closely monitored for deterioration during NHF therapy and the potential requirement for invasive ventilation, it is recommended that NHF is initiated in an emergency department or pediatric intensive care unit where sufficient trained staff are available for patient monitoring. When the patient has been stable for several hours it may then be possible to transfer them to a general ward.

Beneficial effects: Pressures generated during NHF oxygen therapy prevent pharyngeal collapse and obstructive apnoea, and support inspiratory effort when patient flow is limited. Accumulating evidence suggests that NHF has positive effects on energy expenditure compared with conventional oxygen therapy, including preserved mucociliary function, prevention of atelectasis and decreased inspiratory work/work of breathing. However, the effects of NHF on the ventilation/perfusion ratio have yet to be clearly established.
Side effects and monitoring: One of the most important benefits of NHF oxygen therapy is the reduction in adverse effects and improved patient comfort associated with delivery of heated and humidified gas. In addition, cutaneous tolerance is better than that for CPAP. One disadvantage is the noise associated with the device, which increases as flow increases, and can reach about 80 dB (higher than that for CPAP systems). Three episodes of pneumothorax and pneumodiastinum have been reported during NHF therapy and there is a risk of air leak syndrome if nasal prongs are too large and occlude the nostril lumen.

CONCLUSION:
Although there is a lack of published data on the clear benefits of NHF oxygen therapy in pediatric patients, use in this setting is increasing. The most studied indication is moderately severe viral bronchiolitis in infants, but accumulating evidence suggest that NHF may have application across a broader range of pediatric ages and diagnoses. NHF systems are easy to use and well tolerated, making them an attractive treatment option.

KEY POINTS:
• Use of NHF oxygen therapy in pediatric indications is increasing.
• Beneficial effects of NHF oxygen therapy in pediatric patients include maintenance of airway patency, decreased work of breathing, reduced energy expenditure and improved mucociliary function.
• NHF oxygen therapy is easy to use in pediatric patients and is well tolerated.
• NHF oxygen therapy for pediatric patients should be initiated in an environment where close monitoring is possible.
• More data are needed to better define the role of NHF oxygen therapy in pediatric indications.
Respiratory support for children in the emergency department

AIM:
This review provides an overview of respiratory support and oxygen delivery in the pediatric emergency setting based on current published literature.

DETAILS:
In pediatric patients with acute respiratory distress, respiratory support aims to prevent severe hypoxemia and maintain oxygen delivery. As excess oxygen is associated with reperfusion injuries, oxygen should be administered with caution and within target arterial oxygen saturation (SaO₂) values. Although these SaO₂ targets vary among international guidelines, the World Health Organization recommend a normal SaO₂ of ≥94%. Oxygen delivery and clearance of carbon dioxide are both necessary for efficient gas exchange. In a ventilated patient, any spontaneous breathing may provide active expiratory effort, and ideally allow for the use of respiratory support with high-flow nasal cannula (HFNC) therapy or non-invasive ventilation (NIV). Potential responders to HFNC or NIV respiratory support include patients who have a decreased respiratory rate, reduced fraction of inspired oxygen (FiO₂), or decreased retractions and accessory muscle use, or patients with improved radiological findings (reversed atelectasis).

High-flow nasal cannula therapy: Use of HFNC therapy has emerged as an alternative to standard oxygen delivery in the pediatric emergency setting, particularly due to its simple application and the limited requirement for patient compliance. HFNC provides respiratory support by delivering heated, humidified gas at high inspiratory flow rates. During the expiratory phase, the patient’s nasopharyngeal dead space is rapidly cleared and carbon dioxide rebreathing is minimized, while the unidirectional flow against the expiratory gas flow creates positive expiratory pressures. The inspiratory flow rate should ideally match the expected maximal inspiratory flow. A flow rate of 2 L/kg/min is suggested, with an upper limit of 40–60 L/min. SaO₂ is maintained between 92% and 98% by titration of the FiO₂, which is reduced to room air at maintained flow rates during weaning of HFNC therapy. After 4 hours in room air, the high flow rate is stopped; however, if an oxygen requirement recurs, HFNC therapy in room air is restarted, with increased FiO₂ as required. Several studies have shown that HFNC therapy decreases the work of breathing in infants aged <12 months at flow rates of 1.5–2 L/kg/min. In observational studies in emergency and intensive care unit (ICU) settings, infants with bronchiolitis responded to HFNC therapy, with reduced heart and respiratory rates within a few hours. A multicenter, randomized clinical trial comparing HFNC therapy with standard oxygen delivery in infants with moderate bronchiolitis is currently ongoing in Australia and New Zealand. Early respiratory support with NIV or HFNC therapy in less severe cases may reduce the occurrence of further respiratory decline.

Non-invasive ventilation: During continuous positive airway pressure (CPAP) therapy, airway pressure is continuously maintained during both the inspiratory and expiratory phase, whereas a greater airway pressure in the inspiratory phase is used during bi-level positive airway pressure therapy. As NIV requires patient cooperation, it can be difficult to perform in pediatric patients due to their limited ability to tolerate wearing a face mask. Therefore, sedation is often required during CPAP, but as this can cause respiratory depression, the type and dose of sedation used needs to be carefully considered. NIV also requires high levels of nursing expertise, is not suitable for patients with decreased consciousness, cardiovascular instability, or reduced upper airway reflexes or control, and should not be used after upper airway surgery, upper gastrointestinal (GI) tract surgery, or upper GI bleeding. NIV can be delivered with a full face mask or nasal mask only, although the latter option is typically only used in patients requiring long-term NIV. In general, CPAP is started at 5 cm H₂O and adapted as needed, with pressures of 10–12 cm H₂O often required. In NIV responders, the work of breathing is clinically reduced, which leads to reductions in heart and respiratory rates. Invasive mechanical ventilation may be necessary in patients for whom an SaO₂ of >92% cannot be maintained with an FiO₂ <60%. In clinical trials, the use of CPAP was shown to be beneficial in pediatric patients with asthma or bronchiolitis; however, these studies were predominantly limited to the pediatric ICU setting.
Transitional phase during intubation and mechanical ventilation: During tracheal intubation, maintaining SaO₂ with airway management can be challenging. Pre-oxygenation is necessary to prevent or limit induction-related tissue hypoxemia, especially prior to rapid-sequence induction, during which a pediatric patient will desaturate in <20 s while breathing room air. Pre-oxygenation before induction with CPAP therapy can recruit alveolar space and prevent hypoxemia. HFNC therapy is an attractive alternative to CPAP that does not require the use of a face mask, and has been used for pre-oxygenation in some adult emergency departments. Induction of anesthesia is also associated with changes in ventilation distribution and reduction in lung volume. As pediatric patients have a smaller functional residual lung capacity than adults, sedation can rapidly lead to an oxygen requirement, even with maintenance of spontaneous breathing. However, ketamine may preserve lung volume in healthy pre-school children when administered for small procedures.

CONCLUSION:
Respiratory support focuses on delivering positive airway pressure, with increases in FiO₂ as required. The use of HFNC and NIV therapy for oxygen delivery in the pediatric emergency setting is increasing. HFNC has emerged as a method of providing inspiratory support, positive expiratory pressure, and oxygen delivery, with a simple application that requires less patient compliance than NIV.

KEY POINTS:
• Respiratory support is necessary in pediatric patients with acute respiratory distress to prevent hypoxemia.
• HFNC therapy has emerged as an alternative to standard oxygen delivery in the pediatric emergency setting.
• HFNC therapy is simple to use, well-tolerated and requires minimal patient cooperation.
• NIV can be used in pediatric patients, although most patients are unable to tolerate the face mask and sedation is usually required.
• HFNC therapy or NIV may potentially be used to provide pre-oxygenation in pediatric patients undergoing anesthetic induction.
High flow nasal cannulae therapy in infants with bronchiolitis

AIM:
To determine if heated humidified nasal high flow (NHF) oxygen therapy was associated with decreased rates of intubation in infants with bronchiolitis admitted to a pediatric intensive care unit (PICU).

METHOD:
In this retrospective study, the charts of 115 infants (age 0.5-24.0 months) with bronchiolitis were reviewed to examine the effect of the introduction of the NHF oxygen therapy system (M8850; Fisher & Paykel Healthcare) in the PICU. Fifty-seven infants were included for analysis in the “before” group (controls) and the outcomes of 58 infants were analyzed after the introduction of NHF therapy.

Use of the NHF system was at the discretion of the attending physician in the PICU. Both infant and pediatric cannulae were available and the size used was selected to fit the child’s nares without occlusion.

The primary objective of the study was to determine whether the availability of NHF oxygen therapy was associated with a decrease in the need for intubation. Secondary outcomes included changes in respiratory measures and whether certain subgroups of infants showed greater benefit (see table below).

RESULTS:
There were no differences between groups in terms of age, weight, gestational age, sex, RSV status, and Pediatric Index of Mortality (PIM2) score; however, more infants in the control group were premature (gestational age <37 weeks; 40% versus 19% of infants in the NHF group). Before the introduction of the NHF system, 57.9% of infants presenting with bronchiolitis received nasal cannula oxygen as their primary means of respiratory support. After the introduction of the NHF system, this was used in 87.9% of infants.

Data for the primary and secondary endpoints are reported in the table. The reduction in the intubation rate, as assessed using logistic regression analysis, was statistically significant both in the unadjusted analysis and after adjustment for age, weight and RSV status (p=0.043 and p=0.049, respectively). The p value after adjustment for age, weight, RSV status and gestational age was 0.072.

Multivariate logistic regression analysis showed that infants with a history of prematurity may benefit more from NHF therapy; the intubation rate in formerly premature infants in the control group was 34.8% compared with 9% in the NHF group but patient numbers were too small to allow statistical comparison. Infants who received NHF oxygen therapy had a greater decrease in respiratory rate one hour after initiation of treatment than those who did not (p<0.001); this effect persisted after adjustment for age, weight, gestational age and requirement for intubation. Infants who did not experience a clinically significant reduction in respiratory rate after the initiation of NHF were more likely to require intubation. The decrease in respiratory rate one hour after initiation of NHF was 14 (± 15) versus 1(± 17) breaths/minute in infants who didn’t versus did require intubation, respectively.

<table>
<thead>
<tr>
<th></th>
<th>CONTROLS (N=57)</th>
<th>NHF OXYGEN THERAPY (N=58)</th>
<th>ABSOLUTE RISK REDUCTION</th>
<th>ADJUSTED DECREASE IN RISK OF INTUBATION WITH NHF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intubation rate, n (%)</td>
<td>13 (23)</td>
<td>5 (9)</td>
<td>14%</td>
<td>65%</td>
</tr>
</tbody>
</table>

Adjusted = regression analysis adjusted for age, weight, respiratory syncytial virus status and gestational age.
DISCUSSION:
There was a reduction in the need for intubation in infants who presented to the PICU with viral bronchiolitis after the introduction of NHF oxygen therapy which persisted after adjustment for age, weight and RSV status. The reduction in respiratory rate observed in patients who were successfully managed with NHF oxygen therapy supports the hypothesis that NHF oxygen therapy decreases work of breathing and delivers continuous positive airway pressure (CPAP), both of which contribute to a reduced requirement for intubation. After the introduction of NHF the median PICU stay for children with bronchiolitis decreased from 6 to 4 days indicating that by decreasing the need for intubation in this group of infants the length of hospital stay also decreases.

CONCLUSION:
NHF oxygen therapy decreased the intubation rate in infants with bronchiolitis. In addition, this method of respiratory support was well tolerated.

KEY POINTS:
• Use of NHF oxygen therapy for respiratory support in infants with bronchiolitis decreases the need for intubation.
• The mechanism of the beneficial effect of NHF oxygen therapy is likely to be decreased work of breathing and delivery of CPAP.
Use of high-flow nasal cannula support in the emergency department reduces the need for intubation in pediatric acute respiratory insufficiency

AIM:
To determine whether the use of high-flow nasal cannula (HFNC) oxygen therapy reduces the need for endotracheal intubation among pediatric patients with acute respiratory insufficiency (ARI) presenting to the emergency department (ED) and subsequently admitted to the intensive care unit (ICU). In addition, the number of days’ use of HFNC oxygen therapy and mechanical ventilation (MV), length of ICU stay and mortality were assessed.

METHOD:
This was a retrospective study of all patients aged <18 years admitted to the pediatric ICU from the pediatric ED with ARI at a single center between January 2006 and December 2009, in the USA. Acute respiratory insufficiency was defined as any acute respiratory illness severe enough to warrant admission to the ICU. Patients were excluded if they had primary central nervous system causes of ARI or a pre-existing tracheostomy, or if they were receiving non-invasive ventilation support at home, intubated prior to arrival in the ED, or not considered candidates for HFNC oxygen therapy.

Patients were assigned to one of three cohorts, depending on the date of admission. Cohort 1 was admitted before the availability of HFNC oxygen therapy (January 2006 through December 2006), cohort 2 was admitted after HFNC therapy became available but before implementation of an institutional guideline on its use and before HFNC therapy was widely used in the ED (January 2007 through June 2008) and cohort 3 was admitted after HFNC therapy was available and the guidelines were implemented, when HFNC was readily available in both the ICU and ED (July 2008 through December 2009). Data were obtained from chart review.

The HFNC system comprised a humidifier (Fisher & Paykel 850) and a continuous flow circuit (Fisher & Paykel RT 329 for children and infants; Fisher & Paykel RT 202 for adolescents). Flow ranges were 2-10 L/min for children and infants, and 5-50 L/min for adolescents; cannula sizes ranged from infant (maximum flow rate 7 L/min) to large adult (maximum flow rate 50 L/min).

RESULTS:
The study included 848 admissions meeting the inclusion criteria; cohorts 1, 2 and 3 included 190, 289 and 369 patients, respectively. There were no significant differences in baseline characteristics of patients in the three cohorts. Mean ages were 4.1-4.8 years and 39-47% of patients in each cohort were female. The most common primary diagnoses were asthma or reactive airway disease (34-47%), bronchiolitis (23-27%) and pneumonia (16-22%).

Following the introduction of the guidelines, the use of HFNC oxygen therapy increased significantly in the ED (19% of patients in cohort 3 versus 8% in cohort 2; p<0.0001) and a non-significant increase was seen in the ICU (23% vs. 18%; p=0.08). The HFNC utilization ratio (HFNC days/total patient days) also increased after the guidelines were introduced (0.35 for cohort 3 vs. 0.19 for cohort 2; p<0.0001).

The use of HFNC oxygen therapy according to guidelines was associated with reduced intubation rates in the ED and overall, and a non-significant reduction in the number of intubations in the ICU, compared with before HFNC became available (see table). After adjustment for baseline characteristics, an 83% reduction in ED intubations was seen in cohort 3 compared with cohort 1 (p=0.001). No significant difference in intubation rates was seen between cohorts 1 and 2. Initiation of HFNC oxygen in the ED rather than in the ICU was associated with a reduction in the rate of subsequent intubation (7.6% vs. 18.1%; p=0.047). HFNC success rates (no requirement for intubation or non-invasive ventilation during illness) did not change significantly after the introduction of the guidelines (88% for cohort 3 versus 84% for cohort 2). There were no significant differences in total ventilator days, the duration of ICU stay, or mortality rates. Guideline-based HFNC oxygen therapy (cohort 3) was associated with reduced intubation rates across ARI types (including asthma/reactive airway disease and bronchiolitis), with the exception of croup. Intubation was performed in 30 patients for whom HFNC was unsuccessful and 75 patients in whom HFNC was not tried.

HFNC oxygen therapy was generally well tolerated and accepted by patients. One patient experienced a major complication attributed to HFNC, bilateral pneumothoraces which developed within several hours of initiation of treatment, occurred prior to the introduction of the guidelines and was considered likely to have been due to improper fitting of the cannula.
**DISCUSSION:**
This appears to be the first study to demonstrate that HFNC oxygen therapy in the paediatric ED is beneficial across different ages and diagnoses of ARI. The use of HFNC oxygen therapy was associated with reduced MV rates in children with ARI compared with the period before HFNC became available. Intubation rates also significantly decreased after HFNC oxygen therapy became readily available in the ED and guidelines on its use were implemented. The lack of significant difference in intubation rates following the introduction of HFNC without guidelines and with limited availability in the ED (cohort 2) compared with pre-HFNC (cohort 1) suggests that guidelines, including an education programme, and greater availability of the HFNC equipment were responsible for its increased use in the pediatric ED and consequently lower intubation rates. HFNC oxygen therapy is potentially cost saving due to reduced use of MV, which leads to reductions in costs associated with administration, sedation, and the management of ventilator-associated complications such as nosocomial pneumonia and airway injury.

**CONCLUSION:**
Early initiation of HFNC oxygen therapy reduces the need for endotracheal intubation and mechanical ventilation in pediatric patients with ARI. Introduction of institutional guidelines on the use of HFNC oxygen therapy increases the rate of its use in the ED and reduces the rate of intubation.

**KEY POINTS:**
- Early initiation of HFNC oxygen therapy is associated with reduced need for intubation or mechanical ventilation in pediatric patients with ARI.
- Guidelines on the use of HFNC oxygen therapy and its availability in the ED are associated with reduced intubation and mechanical ventilation rates.
- Early use of HFNC oxygen therapy is not associated with increased durations of mechanical ventilation or PICU stay.

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<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COHORT 1 (N=190)</th>
<th>COHORT 2 (N=289)</th>
<th>COHORT 3 (N=369)</th>
<th>P-VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UTILISATION, % PTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>HFNC Initiated in ED</td>
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<td>23</td>
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<td>p&lt;0.0001</td>
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<td><strong>MECHANICAL VENTILATION</strong></td>
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<tr>
<td>Intubation in ED</td>
<td>11</td>
<td>10</td>
<td>2</td>
<td>p&lt;0.0001</td>
</tr>
<tr>
<td>Intubation in ICU</td>
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<td>6</td>
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<tr>
<td>Intubation Total</td>
<td>16</td>
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<td>8</td>
<td>p=0.004</td>
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**UTILISATION RATIOS**

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<th>COHORT 1 (N=190)</th>
<th>COHORT 2 (N=289)</th>
<th>COHORT 3 (N=369)</th>
<th>P-VALUE</th>
</tr>
</thead>
<tbody>
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<td>HFNC -</td>
<td>-</td>
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<td>0.35</td>
<td>p&lt;0.0001</td>
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<td>Ventilator</td>
<td>0.41</td>
<td>0.32</td>
<td>0.21</td>
<td>p&lt;0.001</td>
</tr>
</tbody>
</table>

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Reduced intubation rates for infants after introduction of high-flow nasal prong oxygen delivery

AIM:
To describe the experience with the use of nasal high flow oxygen therapy (NHF) in the treatment of infants aged <24 months with respiratory distress admitted to the pediatric intensive care unit (PICU). To compare the ventilatory practices at this PICU with those of all other PICUs in Australia and New Zealand.

METHOD:
A retrospective database review was performed to identify all infants aged <24 months who had received NHF within 24 hours of admission to the PICU over the period January 2005 to December 2009 (n=298). A humidified NHF system was used with a low-resistance cannula [BC3780 and RT329; Fisher & Paykel Healthcare]. Underlying disease was classified as: viral bronchiolitis (n=167); other lung disease (72); upper airway obstruction (8); neuromuscular conditions (10); cardiac conditions (24); or other (17). Respiratory support subgroups were classified as: NHF alone; NHF + noninvasive ventilation (NIV); NHF + NIV + invasive ventilation (INV); NHF + INV. Risk factors for escalation to NIV or INV were investigated.

Specific to infants admitted with viral bronchiolitis, local changes in ventilation practices during the study period were assessed retrospectively using case records from the PICU’s own database. The data from this PICU were then compared with case records from the Australian New Zealand Paediatric Intensive Care (ANZPIC) registry for infants with viral bronchiolitis admitted during 2008.

RESULTS:
The number of infants who needed additional respiratory support with NIV or INV is detailed in the table below.

Infants in the NHF group had a significantly lower PIM2 ROD score and fraction of inspired oxygen (FiO₂) on admission compared with the NHF + NIV group (p<0.01). PICU length of stay was also shorter in the NHF group compared with the NHF + NIV group (p<0.01).

Across the whole group (n=298) there was an overall reduction in respiratory rate and heart rate after NHF commencement (p<0.001). Infants who could be maintained on NHF showed a decrease of >20% in both heart rate and respiratory rate within 90 minutes of the initiation of NHF (both p<0.05 vs. baseline). This rapid response was not evident in the NHF+NIV group. Also, infants with bronchiolitis had the greatest change in heart rate and respiratory rate after initiation of NHF oxygen therapy compared with infants who had other underlying conditions.

The intubation rate for viral bronchiolitis at the study site was 37% in 2005 and 7% in 2009. In comparison, the ANZPIC registry data reported an intubation rate of 28% for viral bronchiolitis in 2008.

The incidence of adverse events including pneumothorax, gastric distension and mucosal injury was monitored. No such events occurred during NHF therapy.
DISCUSSION:
Viral bronchiolitis is the most common reason for non-elective admission to the PICU. This retrospective analysis showed an increase in the proportion of infants with viral bronchiolitis treated with NHF from 13% in 2005 to 66% in 2009. Although it is difficult to demonstrate a cause and effect relationship using a retrospective analysis, a significant reduction in the need for intubation and mechanical ventilation was seen during this period, from 37% in 2005 to 7% in 2009, whereas the ANZPIC registry showed a markedly higher intubation rate of 28%. This suggests that the reduced intubation rate at the study institution is unlikely to have been due to an overall improvement in the standard of care over time. Also, admission criteria to the PICU did not change over the study period. A multicenter randomized controlled trial comparing NHF therapy with standard care is required to definitively assess the efficacy of this intervention in a PICU setting.

CONCLUSION:
NHF is an efficient method of respiratory support and oxygen delivery for infants with respiratory distress. The introduction of NHF to the PICU was associated with a reduction in the requirement for INV in infants with viral bronchiolitis.

KEY POINTS:
• Early improvement in heart rate and respiratory rate (reductions of >20% within 90 minutes) is predictive of the success of NHF oxygen therapy in infants with respiratory distress admitted to the PICU.
• The introduction of NHF oxygen therapy in the PICU coincided with a significant reduction in the need for intubation in infants with viral bronchiolitis.

Fisher & Paykel Healthcare has provided funding for the study.
High-flow nasal cannula oxygen therapy for infants with bronchiolitis: pilot study

AIM:
To investigate the clinical use and safety of nasal high-flow (NHF) therapy in a regular pediatric ward for infants with bronchiolitis.

METHOD:
This pilot study enrolled infants aged <1 year with bronchiolitis who required oxygen therapy during treatment in a pediatric ward setting. A standard treatment control group was identified retrospectively and included infants who met the study inclusion criteria and were treated over the same time period but did not get referred for enrolment in the trial. NHF therapy was delivered via appropriately-sized nasal cannulae and circuit (RT329, BC3780 and BC2745; Fisher & Paykel Healthcare) at an initial flow rate of 2 L/kg/min, titrated up to 10 L/kg/min. Heated humidification was provided using an MR850 device (Fisher & Paykel Healthcare). The fraction of inspired oxygen (FiO₂) was titrated to maintain oxygen saturation (SpO₂) at 94–98%. NHF oxygen therapy was discontinued when the FiO₂ could be reduced to 0.21 with SpO₂ maintained at ≥94%, but could be restarted at the same rate if SpO₂ fell below this cut-off value and titrated upwards if required to achieve the target SpO₂. This process could be repeated until the patient was able to remain off NHF oxygen therapy.

RESULTS:
Demographic and physiologic characteristics at baseline were similar in the NHF group (n=61) and the control patients (n=33). The proportion of patients requiring transfer to the pediatric intensive care unit (PICU) in each group (nonresponders) is shown in the table. Length of hospital stay was similar in the NHF and control groups (median 92 hours).

In both the NHF and control groups, patients who responded to therapy and remained on the pediatric ward had a significant reduction in heart rate during the first 60 minutes of treatment. Respiratory rate also decreased significantly in responders, within 60 minutes in the control group and within 180 minutes in the NHF group. In contrast, nonresponders had no change or an increase in both heart rate and respiratory rate after initiation of treatment (NHF or standard oxygen therapy).

There were no serious adverse events in either the NHF or control group, and no patients required intubation and mechanical ventilation.

<table>
<thead>
<tr>
<th></th>
<th>CONTROL (N=33)</th>
<th>NHF OXYGEN THERAPY (N=61)</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PICU admission required, n (%)</td>
<td>10 (31)</td>
<td>8 (13)</td>
<td>4.086 (1.0, 8.2)*</td>
</tr>
</tbody>
</table>

CI, confidence interval; OR, odds ratio. * p=0.043.
CONCLUSION:
NHF therapy can be safely administered in a pediatric ward setting. Monitoring of heart rate and respiratory rate allows patients who are unlikely to respond to therapy to be identified early and reviewed for potential transfer to the PICU. In this hospital, use of NHF therapy on a regular ward and the resulting reduction in PICU admissions has a predicted cost saving of approximately A$1.2 million.

KEY POINTS:
• NHF therapy can be safely administered in a pediatric ward environment.
• Patients who will not respond to NHF therapy can be identified based on a lack of reduction in heart rate and respiratory rate early after treatment initiation.
• Use of NHF therapy on pediatric wards can reduce PICU admissions and may therefore result in substantial cost savings.
**Comparative evaluation of high-flow nasal cannula and conventional oxygen therapy in paediatric cardiac surgical patients: a randomized controlled trial**

**AIM:**
To compare the effects of standard oxygen therapy and NHF oxygen therapy on carbon dioxide (CO2) elimination in pediatric cardiac surgery patients who had undergone cardiopulmonary bypass (CPB). Secondary objectives were to compare the two types of oxygen therapy with respect to other respiratory parameters, the rate of atelectasis, need for additional respiratory support, and occurrence of complications.

**METHOD:**
This single-center, randomized, open-label comparative study was conducted in a 14-bed pediatric intensive care unit (PICU) between May 2012 and January 2013. Eligible patients were aged <18 months and had undergone elective cardiac surgery for congenital heart disease, with cardiopulmonary bypass (CPB). Patients were randomized to standard oxygen therapy or NHF oxygen therapy after weaning from CPB. Standard oxygen therapy was administered via nasal cannula (Salter Labs E1601) at a maximum flow rate of 2 L/min. NHF oxygen therapy was delivered via Optiflow RT329 (maximum flow rate 8 L/min) for infants weighing <4 kg or Optiflow Junior RT330 (maximum flow rate 20 L/min) for infants weighing >4 kg. In all patients, inspired gas was heated to 36.7ºC and humidified (Fisher & Paykel Healthcare). The fraction of inspired oxygen (FiO2) was adjusted to achieve oxygen saturation (SaO2) of >90% in non-cyanotic infants and >75% in cyanotic infants. Arterial blood gases, heart rate, blood pressure and respiratory rate were determined before extubation and at 1, 6, 12, 24 and 48 hours after extubation. Patients were assessed every 4 hours for the presence of nasal ulcers or gastric distension, and the need for supplemental oxygen.

**RESULTS:**
Of 104 eligible patients, 94 were enrolled in the study and 89 were included in the analysis. There were no significant differences in carbon dioxide pressure (PaCO2) between the standard oxygen therapy and NHF oxygen therapy groups. Oxygen pressure (PaO2) and PaO2/FiO2 at 6, 12, 24 and 48 hours after extubation were significantly higher in NHF versus standard oxygen therapy recipients (all p<0.05). On multivariate regression analysis, use of NHF was the only significant predictor of higher PaO2/FiO2 at 6 and 24 hours (r²=0.315, p=0.006 and r²=0.407, p=0.002, respectively). Treatment outcomes and complications are shown in the table. No other complications were observed, and median ventilation time and PICU length of stay were similar in the two treatment groups.

<table>
<thead>
<tr>
<th>NUMBER OF PATIENTS (%)</th>
<th>STANDARD OXYGEN THERAPY (N=46)</th>
<th>NHF OXYGEN THERAPY (N=43)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment failure</td>
<td>7 (15)</td>
<td>0*</td>
</tr>
<tr>
<td>Reintubation</td>
<td>2 (4.3)</td>
<td>2 (4.6)</td>
</tr>
<tr>
<td>Atelectasis</td>
<td>5 (11)</td>
<td>5 (11)</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>1 (2)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Cyclothorax</td>
<td>1 (2)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Pleural effusion</td>
<td>2 (4)</td>
<td>3 (7)</td>
</tr>
<tr>
<td>Abdominal distension requiring therapy discontinuation</td>
<td>0</td>
<td>2 (5)</td>
</tr>
</tbody>
</table>

* p=0.008 vs standard oxygen therapy.
CONCLUSION:
This study is the first randomized, controlled trial to investigate the use of NHF oxygen therapy in infants undergoing cardiac surgery. NHF oxygen therapy did not decrease PaCO₂ compared with standard oxygen therapy in pediatric cardiac surgery patients after CPB. However, NHF was significantly better for improving PaO₂ and PaO₂/FiO₂, and was well tolerated.

KEY POINTS:
• NHF and standard oxygen therapy have similar effects on PaCO₂ in pediatric cardiac surgery patients after CPB.
• NHF oxygen therapy improves PaO₂ and PaO₂/FiO₂ to a significantly greater extent than standard oxygen therapy in pediatric cardiac surgery patients after CPB.
• NHF therapy was well tolerated in pediatric cardiac surgery patients after CPB.
The effect of high flow nasal cannula therapy on the work of breathing in infants with bronchiolitis

AIM:
To assess the effect of nasal high flow (NHF) oxygen therapy on work of breathing (WOB) in infants with bronchiolitis compared to those with non-obstructive airways (cardiac disease).

METHOD:
Patients admitted to the pediatric intensive care unit between May 2012 and February 2013 who had either bronchiolitis or congenital heart disease were eligible for inclusion in this prospective interventional trial. Infants were treated with NHF oxygen therapy (Optiflow Junior RT330; Fisher & Paykel Healthcare) via an appropriately-sized nasal cannula (Optiflow Junior Nasal Cannula; Fisher & Paykel Healthcare) and with heated humidification (MR850; Fisher & Paykel Healthcare). Mouth closure was obtained either spontaneously or by use of a pacifier. The fraction of inspired oxygen (FiO₂) was adjusted to maintain oxygen saturation (SpO₂) at 94–98%. Measurements were made after a 10-minute stabilization period without NHF and with NHF at 2 L/kg/min.

Electrical activity of the diaphragm was recorded using an Edi catheter, which was also used to determine esophageal pressure; a respiratory inductance plethysmograph (RIP, Respitrace Q.D.C.; Care Fusion Corporation) was used to determine the volume state of the lung. WOB was calculated as the integral of the esophageal pressure curve during inspiration multiplied by the respiratory rate (RR).

RESULTS:
Twenty-eight infants were enrolled (14 in each patient group) and 24 (12 in each group) had technically-sufficient data and were included in the analysis. NHF oxygen therapy was associated with a reduction in the RR from 60 to 54 breaths/min in infants with bronchiolitis (p=0.004 vs baseline) and from 48 to 41 breaths/min in those with congenital heart disease. NHF oxygen therapy was associated with significant off-loading of the diaphragm, as shown by significant decreases in Edi peak signal (EdiMAX) and amplitude (EdiMAX) compared with before NHF (both p<0.05). Cardiac infants also showed significant reductions from baseline in EdiMAX and EdiMAX during NHF, but these were of a smaller magnitude than those in bronchiolitis patients. End-expiratory lung volume in infants with bronchiolitis was significantly increased by NHF (p=0.013 vs baseline), and the amplitude of tidal breathing was significantly decreased (p=0.017); changes in cardiac infants were qualitatively similar but were numerically smaller and did not always reach statistical significance versus baseline. NHF therapy had no significant effect on minimum and maximum esophageal pressure in either patient group. However, WOB decreased significantly from baseline after NHF therapy in the bronchiolitis group, as shown by significant reductions in the pressure-rate product (PRP) and pressure-time product (PTP) (p=0.004 and p=0.003, respectively). Small, non-significant reductions in PRP and PTP were seen in the cardiac group.

CONCLUSION:
In infants with bronchiolitis, NHF oxygen therapy at a flow rate of 2 L/kg/min offloads the diaphragm and reduces WOB. The effects of NHF were similar, but of a smaller magnitude, in infants with cardiac disease but without airway obstruction.

KEY POINTS:
- NHF oxygen therapy at 2 L/kg/min decreases work of breathing in infants with bronchiolitis.
Is treatment with a high flow nasal cannula effective in acute viral bronchiolitis? A physiologic study

AIM:
To measure pharyngeal pressure provided by nasal high flow (NHF) oxygen therapy at flow rates of 1–7 L/min in infants aged <6 months hospitalized in the pediatric intensive care unit (PICU) with respiratory syncytial virus (RSV) bronchiolitis.

METHOD:
All infants aged <6 months with acute viral bronchiolitis and mild respiratory distress hospitalized in the PICU were eligible for the study. Patients were treated with NHF oxygen therapy (RT329 system with MR850 humidifier; Fisher & Paykel Healthcare) delivered via an oxygen therapy nasal cannula (BC2745 or BC2755; Fisher & Paykel Healthcare). A pacifier was used to limit air leak from the mouth. The fraction of inspired oxygen (FiO₂) was adjusted to maintain oxygen saturation (SpO₂) at 94–98%. An esophageal pressure probe was inserted for simultaneous measurement of esophageal and pharyngeal pressures, which were determined after 10 minutes' rest at baseline (NHF flow rate 1 L/min) and during NHF at flow rates of 4, 6 and 7 L/min.

RESULTS:
Of 38 eligible infants presenting between December 2011 and March 2012, 21 patients were included. Mean pharyngeal pressure increased from 0.2 cmH₂O (95% confidence interval [CI] –0.2, 0.7) at baseline to 4 cmH₂O (3, 5) at 7 L/min. There was a significant correlation between pharyngeal pressure and flow (r=0.65, p<0.0001), but only NHF flow rates of ≥6 L/min were associated with pharyngeal pressure increases that provided positive pressure values during both inspiration and expiration. An NHF flow of ≥2 L/kg/min was associated with generation of a mean pharyngeal pressure of ≥4 cmH₂O with sensitivity and specificity of 67% and 96%, respectively, and positive and negative predictive values of 75% and 94.5%, respectively.

NHF at 7 L/min significantly reduced the respiratory rate (p=0.007) and the modified Woods Clinical Asthma Score (m-WCAS) (p=0.0096) compared with baseline; there were no significant changes in oxygen requirements or saturation. Both breathing pattern (based inspiratory time) and respiratory effort (based on esophageal pressure) decreased significantly from baseline during NHF at 7 L/min.

None of the infants treated with NHF had complications during therapy. There were no cases of air leak syndrome, and no patient required back-up respiratory support with nasal continuous positive airway pressure or intubation.

CONCLUSION:
NHF oxygen therapy at a flow rate of ≥2 L/kg/min is associated with clinically-relevant pharyngeal pressure (i.e. ≥4 cmH₂O), improves the breathing pattern and unloads respiratory muscles in infants aged <6 months with acute viral bronchiolitis.

KEY POINTS:
• NHF oxygen therapy at a flow rate of ≥2 L/kg/min is associated with clinically-relevant pharyngeal pressure in infants aged <6 months with RSV bronchiolitis.
• NHF oxygen therapy at a flow rate of ≥2 L/kg/min unloads respiratory muscles in infants aged <6 months with RSV bronchiolitis.
• NHF oxygen therapy at a flow rate of ≥2 L/kg/min is well tolerated in infants aged <6 months with RSV bronchiolitis.
High-flow nasal cannula oxygen for bronchiolitis in a pediatric ward: a pilot study

AIM:
To evaluate the feasibility and respiratory effects of nasal high flow (NHF) oxygen therapy for the treatment of infants with moderate-to-severe bronchiolitis treated in a pediatric ward.

METHOD:
This prospective, observational pilot study included neonates and infants (age 7 days to 12 months) with moderate-to-severe bronchiolitis needing oxygen supplementation who received NHF on a pediatric ward at the University of Padova Hospital, Italy, between November 2011 and April 2012. Standard oxygen therapy (2 L/min) was given in the emergency department, and NHF was initiated after admission to the pediatric ward. Prior to the study, pediatric ward medical and nursing staff received a half-day training course on NHF oxygen therapy use.

NHF was provided using the MR850 humidification system, RT329 Kit and Optiflow oxygen cannulas (Fisher & Paykel Healthcare). Nasal cannula were chosen to fit the nares without occlusion. Initial flow rate was the patient’s weigh in kg + 1, to a maximum of 8 L/min, and gases were delivered at 37°C. The fraction of inspired oxygen (FiO₂) was adjusted to achieve oxygen saturation (SpO₂) of ≥ 94%. When adequate SpO₂ was maintained with a FiO₂ of 25%, the flow rate was decreased by 1 L/min every 6 hours. At a flow rate of 2 L/min, NHF was switched to standard oxygen therapy if necessary. SpO₂, respiratory rate (RR), heart rate (HR), body temperature and end-tidal carbon dioxide (ETCO₂) were recorded at baseline, and at 1, 3, 6, 12, 24, 36 and 48 hours after the initiation of NHF.

RESULTS:
Twenty-seven of 38 eligible patients were enrolled in the study. Compared with baseline, NHF significantly improved SpO₂, ETCO₂, and RR (Table). There were no significant changes in HR, FiO₂ and the prevalence of fever >37.5 °C after switching from standard oxygen therapy to NHF oxygen therapy.

NHF oxygen therapy was well tolerated and did not need to be interrupted in any patient during the study. There were no complications and no cases where escalation of ventilator support was required.

<table>
<thead>
<tr>
<th>Baseline†</th>
<th>SPO₂ (%)</th>
<th>RR (BREATHS/MIN)</th>
<th>ETCO₂ (MMHG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline†</td>
<td>88 (85-91)/97 (91-100)</td>
<td>70 (40-88)</td>
<td>37 (27-50)</td>
</tr>
<tr>
<td>1 hour</td>
<td>97 (93-100)</td>
<td>50 (30-80)</td>
<td>30 (20-41)</td>
</tr>
<tr>
<td>3 hours</td>
<td>98 (94-100)</td>
<td>54 (38-75)</td>
<td>29 (20-42)</td>
</tr>
<tr>
<td>6 hours</td>
<td>98 (94-100)</td>
<td>50 (30-70)</td>
<td>30 (17-50)</td>
</tr>
<tr>
<td>12 hours</td>
<td>99 (95-100)</td>
<td>47 (27-80)</td>
<td>30 (19-42)</td>
</tr>
<tr>
<td>24 hours</td>
<td>98 (94-100)</td>
<td>50 (30-80)</td>
<td>29 (19-41)</td>
</tr>
<tr>
<td>36 hours</td>
<td>99 (94-100)</td>
<td>42 (25-60)</td>
<td>29 (15-42)</td>
</tr>
<tr>
<td>48 hours</td>
<td>98 (93-100)</td>
<td>45 (30-60)</td>
<td>29 (18-36)</td>
</tr>
</tbody>
</table>

Data are median (range). SpO₂ at baseline was measured during breathing of room air (*) and during standard oxygen therapy (#). ETCO₂, end-tidal carbon dioxide; RR, respiratory rate; SpO₂, oxygen saturation.

†Values immediately prior to the start of NHF were used.
* p≤0.001 vs baseline (room air); † p<0.05 vs baseline (standard oxygen therapy); ‡ p≤0.001 vs baseline
CONCLUSION:
Administration of NHF oxygen therapy to infants with moderate-to-severe bronchiolitis improves respiratory parameters, is feasible, and safe.

KEY POINTS:
• Use of NHF oxygen therapy on pediatric wards is feasible.
• NHF oxygen therapy improves respiratory parameters in neonates and infants with moderate-to-severe bronchiolitis treated in a pediatric ward.
• NHF oxygen therapy is safe and well tolerated in neonates and infants with moderate-to-severe bronchiolitis treated in a pediatric ward.
95% CONFIDENCE INTERVAL:
A statistical measure showing that 95% of the results for that parameter lie within the range quoted.

ACUTE RESPIRATORY INSUFFICIENCY (ARI):
A condition where the lungs are unable to function properly and maintain the normal processes of oxygen uptake and carbon dioxide removal.

AIRWAY RESISTANCE:
A measure of the impedance to ventilation caused by the movement of gas through the airways. This measurement is calculated as the change in pressure along a tube divided by flow.

APNEA OF PREMATURITY (AOP):
A phenomenon that occurs in premature babies when the part of the central nervous system that controls breathing is not yet mature enough to allow continuous breathing. This results in large bursts of breath followed by periods of shallow or stopped breathing.

ATELECTASIS:
Incomplete expansion of a portion of the lung or the whole lung.

BRONCHOPULMONARY DYSPLASIA (BPD) OR CHRONIC LUNG DISEASE:
Most common sequelae of prolonged mechanical ventilation characterized by chronic respiratory failure. Several factors contribute to the chronic lung damage such as prematurity with incomplete lung development, pulmonary barotraumas, oxygen toxicity, pulmonary edema, inflammatory reaction and airway obstruction.

BRONCHIOLITIS:
Acute viral infection of the small air passages of the lungs called the bronchioles. Most commonly caused by RSV (Respiratory Syncytial Virus) in infants.

BODY TEMPERATURE AND PRESSURE SATURATION (BTPS):
Body temperature, atmospheric pressure and saturated with water vapor. Equivalent to core temperature saturated with water vapor (37°C, 44mg/L).

CARDIOPULMONARY BYPASS (CPB):
A technique that temporarily takes over the function of the heart and lungs during surgery, maintaining the circulation of blood and the oxygen content of the body.

CONTINUOUS POSITIVE AIRWAY PRESSURE (CPAP):
A technique of respiratory therapy in which airway pressure is maintained above atmospheric pressure throughout the respiratory cycle by pressurization of the ventilatory circuit.

DEAD SPACE:
Volume in the airway path that is common to both the inspiratory and expiratory passages. Volume of gas that does not participate in gas exchange. It is ventilated but NOT perfused by the pulmonary circulation:
- Alveolar dead space:
  Volume of gas ventilating unperfused alveoli that has no blood perfusion (shunt or pulmonary embolism).
- Anatomic dead space:
  Volume of gas within the conducting zone of the lungs and upper airway. (Amount of volume that does not enter the alveoli.)
- Mechanical dead space:
  Expired air that is re-breathed through connecting tubing.
- Physiological dead space:
  Anatomic and alveolar dead space.

ED:
Emergency Department

ENDOTRACHEAL TUBE (ETT):
A tube inserted through the mouth or nose into the trachea to maintain an unobstructed airway.

END TIDAL CARBON DIOXIDE (ETCO₂):
The level of carbon dioxide in expired gases at the end of expiration.

EXTUBATION:
Withdrawing an endotracheal tube (ETT) from a patient's airway.

FRACTION OF INSPIRED OXYGEN (FIO₂):
The proportion of oxygen in the air that is inspired.

FULL-TERM:
An infant born between 37 and 40 weeks gestation.

FUNCTIONAL RESIDUAL VOLUME:
The volume in the lungs at the end-expiratory position.

GESTATIONAL AGE:
Period of time between conception and birth.

HEATED HUMIDIFIER (HH):
A humidifier device that heats and humidifies the inspiratory flow of gas that is delivered to the patient.

INFANT:
Children greater than 1 month to 2 years of age.

INTUBATION:
The insertion of an ETT or tracheostomy tube into the trachea.
INVASIVE VENTILATION (INV):
The use of an invasive artificial airway to mechanically assist or replace spontaneous breathing, when patients cannot do so on their own.

LOW BIRTH WEIGHT (LBW):
Birth weight less than 2500g

LUNG COMPLIANCE:
The ability of the lungs to stretch during a change in volume relative to an applied chamber pressure.

MECHANICAL VENTILATION (MV):
The use of an invasive artificial airway to mechanically assist or replace spontaneous breathing, when patients cannot do so on their own.

NASAL HIGH FLOW (NHF) THERAPY:
A technique to provide a high flow of heated, humidified oxygen and air to patients requiring respiratory support, delivered through nasal cannula. Also known as High flow nasal cannula (HFNC)

NONINVASIVE VENTILATION (NIV):
The delivery of ventilatory support without the need for an invasive artificial airway.

OXYGEN SATURATION (SPO2):
Oxygen saturation as measured by pulse oximetry

PARTIAL PRESSURE OF OXYGEN (PAO2):
The part of total blood gas pressure exerted by oxygen gas; a measure of how much oxygen is dissolved in the blood and how well oxygen is able to move from the airspace of the lungs into the blood

PEDIATRIC:
Referring to children up to 21 years of age; usually found in the PICU.

PEDIATRIC INDEX OF MORTALITY (PIM2):
A mortality prediction model for children in intensive care

PICU:
Pediatric Intensive Care Unit

PNEUMONIA:
Infection in one or both of the lungs by bacterial or viral infection

PNEUMOTHORACES:
Condition in which air escapes from the lungs into the chest cavity and compresses the lungs

PNEUMOTHORAX:
Air or gas in the pleural space

POSITIVE END EXPIRATORY PRESSURE (PEEP):
It is a pressure above atmospheric pressure in the airway throughout the expiratory phase of positive pressure ventilation. PEEP is used during mechanical ventilation to improve oxygenation.

POSITIVE END INSPIRATORY PRESSURE (PIP):
The highest pressure applied to the lungs during inspiration

PRETERM:
An infant born before 37 weeks gestation regardless of their weight. Usually the preterm infant are found in the NICU of the hospital on some form of respiratory support. They can be further divided into:

- Moderate to late preterm:
  32 to <37 weeks gestation
- Very preterm:
  28 to <32 weeks gestation
- Extremely preterm:
  <28 weeks gestation

RELATIVE HUMIDITY (RH):
The maximum amount of water a gas can hold at a given temperature.

RESPIRATORY DISTRESS SYNDROME (RDS):
A lung disease of the newborn, most frequently occurring in premature infants, that is caused by abnormally high alveolar surface tension as a result of a deficiency in lung surfactant; also called hyaline membrane disease.

RESPIRATORY RATE:
The amount of breaths over a specified time period.

TIDAL VOLUME (VT):
Volume of air inspired or expired with each normal breath. The amount of gas delivered to a patient in one breath.

TRACHEOSTOMY:
Creation of an opening into the trachea through the neck, with insertion of an tube to facilitate passage of air or evacuation of secretions.

VERY LOW BIRTH WEIGHT (VLBW):
Infants with birth weight less than 1500g

WORK OF BREATHING (WOB):
The force required to expand the lung against its elastic properties.