DOI- 10.21304/2016.0304.00142

Review Article

Humidified High-Flow Nasal Cannula Oxygen Therapy in Children- A narrative review

Sajith Kesavan*, Bala Ramachandran**

*Senior consultant, Pediatric Intensive Care, **Head of the Department of Intensive Care & Emergency Medicine and Medical Director, Kanchi Kamakoti CHILDS Trust Hospital and the CHILDS Trust Medical Research Fund (CTMRF), Chennai

Received: 06-Oct-16/Accepted: 21-Oct-16/Published online: 22-Nov-16

ABSTRACT

Introduction: Heated Humidified High flow nasal cannula (HFNC) is a promising noninvasive respiratory support that is gaining popularity in both adults and children because of excellent patient tolerance and ease of administration in varying etiologies of respiratory distress. **Objectives:** of the current article are to review the physiology and practical aspects of HFNC and appraise available evidence with regard to the utility of HFNC in Pediatrics. **Results:** Prospective studies have established safety and feasibility of HFNC in preterm neonates with respiratory distress and infants with bronchiolitis. Studies suggest that it is equivalent to noninvasive CPAP in these conditions and may have some advantages. Recently a randomized control study in adults with acute hypoxemic respiratory failure have shown a mortality benefit, in addition to decreased intubation rates in the severely hypoxemic subgroup. **Conclusions:** Current evidence suggests that HFNC is a well tolerated and feasible respiratory support across different age groups and indications in the Pediatric ICU and Emergency Room. It is not inferior to the alternate modes of noninvasive positive pressure ventilation and may have some advantages over conventional forms of non-invasive respiratory support.

Key words: heated humidified high flow nasal cannula, non invasive ventilation, bronchiolitis, acute hypoxemic respiratory failure

Introduction

Heated Humidified High Flow Nasal Cannula (HFNC) therapy was originally described as a mode of respiratory therapy in premature neonates[1]. It is now being increasingly used in the management of acute respiratory failure in older infants, children and adults. A therapy which originally began as an alternative to Continuous Positive Airway Pressure (CPAP) in premature babies with apnea of prematurity[1] is now gaining wide acceptance as a first line respiratory support across wide age groups and indications. This mode of respiratory support is also finding its way to use in different settings like PICU (Pediatric intensive care unit), ward, Emergency Department (ED), Operating Rooms (OR) and also interfacility transport of critically ill children.

Correspondence

Dr Sajith Kesavan, Senior Consultant, Pediatric Intensive Care, Kanchi Kamakoti CHILDS Trust Hospital, 12A, Nageswara Road, Nungambakkam, Chennai-600034.
Phone: +919526746319. Email: ksajith120@yahoo.com

Nasal cannulae are a well-established mode of oxygen delivery but are limited by poor tolerance of flows of more than 2 liters per min (LPM) which are usually well below patient's inspiratory flow rates in respiratory distress. High flow systems deliver an oxygen-gas mixture that may meet or exceed patient's spontaneous inspiratory demand[2]. Traditionally, gas flow rates exceeding 1-2 LPM in neonates were considered high flow but recently flows up to 8 LPM in toddlers and up to 60 LPM have been used in adults[2,3]. There is currently no single, simple definition of high flow.

The key determinants of effectiveness would depend on the flow delivered and CPAP generated. The flow should match or exceed the patient's inspiratory demand (which is dependent on the size of the patient, severity of respiratory distress). The amount of positive pressure or CPAP generated is affected by leak around the nasal cannula and through the mouth, in addition to the flow rates[4]. Clinical effectiveness is further determined by patient tolerance of the nasal cannula and the high flow rates. Based on physiological studies by Judith L. Hough et al, flow rates more than 1.7 L/kg/min (rounded to 2 L/kg/min) were recommended[5] .There is no recommendation on the upper flow limits but in various studies of infants with bronchiolitis; flow rates of 2 L/kg/min was well tolerated[6]. These high flow rates need heating and humidification. Devices that can effectively heat and humidify gas at very high flow rates are considered heated humidified high flow nasal cannulae. The advantages of heating and humidification is to prevent drying of nasal passages, mucosal injury and impaired secretion clearance, which is seen with dry, cold air at high flow rates[2].

Figure 1: Heated High Flow nasal cannula device (courtesy Fisher and Paykel Health care

Mechanism of action[7]

1. Washout of nasopharyngeal dead space, thereby improving alveolar ventilation and facilitating CO2 removal. This effect is more pronounced in smaller patients.
2. Reduction in upper airway resistance, which constitutes up to 50% of the whole respiratory system resistance. HFNC reduces resistance by stenting the upper airways and providing adequate flow rates to match inspiratory flow. This, in turn, decreases work of breathing.
3. Provision of positive distending pressure thereby helping in alveolar recruitment. This effect depends on flow rate, leakage via mouth, patient weight and nasal cannula size.
4. Provision of adequately warmed and humidified gas to the conducting airways improves conductance and pulmonary compliance compared to cooler, dry gas.

HFNC device is a closed system which consists of the specially designed nasal cannula, a flow generator, an air oxygen blender and a respiratory gas humidifier. Figure 1 Shows a HFNC device.

Settings

Initiation, escalation and weaning protocols vary widely.

In infants, flow rates (greater than 2 LPM) are usually adjusted to body weight i.e. 2 L/Kg/min up to maximum of 25 LPM[8]. In children flow rates are greater than 6 L/min and may be up to 20 to 30 LPM (closer to 1L/kg/min)[3]. Most protocols use 2 L/kg for first 10 kg body weight and additional 0.5 L/Kg for each Kg above 10 Kg. $Fi0_2$ is set to achieve saturation greater than 92%. Gas temperature is set to 34-37^0 C and adjusted to limit the condensation in the tubings. Nasal cannula size is usually half the nostril diameter[9]. It might be useful to reduce the mouth leaks with a pacifier in smaller infants.

Escalation (changing to noninvasive CPAP or intubation) is based on assessment of consciousness, airway patency, respiratory rate, and work of breathing, $Sp0_2$, heart rate and patient comfort[8]. Success of HFNC is indicated by decrease in respiratory rate, work of breathing, heart rate and $Fi0_2$ requirement along with improvement in patient comfort. Responders showed a decrease in respiratory rate and heart rate within 90 minutes of the start of HFNC therapy compared to no change in HR and RR in nonresponders in a retrospective study by A Schibler et al in infants with bronchiolitis[10].

Predictors of failure (need for intubation or non invasive CPAP) of HFNC were higher venous $PC0_2$ (>50mm HG), lower pH (<7.30)and respiratory rate > 90 th centile at the time of initiation in a study by Kelly GS et al[11]. Higher pre therapy $PC0_2$ and failure to reduce respiratory rate predicted the need for intubation in bronchiolitis in a study by Abboud PA et al[12]. Absence of normalization of heart rate, respiratory rate and failure of $Fi0_2$ to fall to below 0.5 during first 1-2 hour were indicators of therapy failure[6] in a study by Mayfield S et al.

Weaning practices from high flow also vary across different units. Generally, there is no need for a prolonged weaning process. Once the indication for using HFNC has resolved and the patient is stable in less than 0.4, $Fi0_2$ patient can be transitioned to low flow O2 via standard nasal prong therapy[8].

Indications of HFNC

Over the last decade a lot of evidence from observational studies has emerged supporting its use for different indications establishing feasibility, safety and equivalence to noninvasive CPAP support. These include preterm neonates with respiratory distress and infants with bronchiolitis, transport of critically ill children and in respiratory distress of varying etiologies in ED. A randomized control study in adults has shown a mortality benefit of HFNC in patients with acute hypoxemic respiratory failure[13].

HFNC in neonates

HFNC has similar rates of efficacy to other forms of non invasive respiratory support in preterm neonates for preventing treatment failure, death and CLD. Most evidence is available for its use as post extubation support where it causes less nasal trauma and is also associated with less pneumothorax compared with nasal CPAP. Further evidence is required comparing HFNC with other forms of non-invasive respiratory support immediately after birth and for weaning from invasive ventilation[14].

HFNC in infants and older children

Currently there is more evidence available to allow determination of safety or efficacy of HFNC as a form of respiratory support in children in infants with bronchiolitis[15] than in other etiologies of respiratory distress.

Infants with Bronchiolitis in PICU setting

In infants with a clinical diagnosis of bronchiolitis, available evidence indicates that HFNC therapy is feasible and well tolerated[10,16,6]. Physiological studies have demonstrated reduced work of breathing and improved gas exchange[5,17]. Before and after studies suggest that initiation of HFNC therapy decreases the need for intubation in bronchiolitis[10]. One randomized control trial comparing it with hypertonic saline did not find any superiority over hypertonic saline in bronchiolitis[18]. An ongoing multicenter randomized trial is comparing standard sub nasal oxygen and HFNC therapy in infants with bronchiolitis[8].

Other etiologies of respiratory distress

A retrospective study in the PICU showed that HFNC therapy is similar in effectiveness to nasal CPAP in children with moderate to severe respiratory distress, across a range of diagnoses. In this population, 25% of patients treated with HFNC therapy required escalation to invasive ventilation[19].

Emergency Department, Pediatric ward and inter facility transfer

A study by Kelly G S et al analyzed the outcome of infants and children presenting to an emergency department including a range of diagnoses (46% were bronchiolitis) with respiratory distress. Infants with bronchiolitis were the least likely to get intubated in this cohort and most patients responded to HFNC therapy within first three hours of HFNC therapy initiation[11]. A pilot study in the ED of infants with bronchiolitis concluded that HFNC outside the PICU is safe and non responders can be identified within first 2 hours by monitoring HR and RR[6]. Bressan et al concluded from their pilot study that HFNC is feasible for moderate to severe bronchiolitis in a general pediatric ward[20]. In a retrospective single center study of children under 2 years of age transported by a specialized pediatric retrieval team to PICU, HFNC significantly decreased the number of children requiring retrieval on invasive ventilation, without increasing number of children needing intubation in first 24 hours after retrieval[21]

Other indications

HFNC was found to be safe and improved PO_2 in infants post elective cardiac surgery after extubation in a single center prospective randomized control trial [22]. One study has shown its successful use in obstructive sleep apnea in home settings[23] .

HFNC in adults

Recently the FLORALI study has concluded in a randomized control trial in adults with non hypercapnic hypoxemic respiratory failure that high flow oxygen as compared with standard oxygen or noninvasive ventilation resulted in reduced 90-day mortality. Even though it did not show a significant difference in the primary outcome of reducing intubation rates, the subgroup with severe hypoxemia showed significantly decreased intubation rates which may have led to the overall mortality benefit[13]. A concern raised with the study by Kang et al with HFNC was that it delays intubation and increased mortality[24]. But a closer analysis of literature indicates that this may not be the case if decision to intubate is taken within 24-48 hours following initiation and supported by pre specified criteria for intubation[25]

There are other potential areas of use for HFNC which are being explored.

1. Post extubation[26] - HFNC is an appealing device to reverse post extubation atelectasis and improve oxygenation. HFNC may play a role in preventing reintubation in moderately hypoxemic patients (which is being evaluated in trials), but further studies are needed to better define which patient can benefit and the timing of application.
2. Preoxygenation for endotracheal intubation in hypoxemic patients - the most frequently reported complication during endotracheal intubation is severe desaturation under 80%, notably for hypoxemic patients. One before and after single center trial[27] showed promise in decreasing the prevalence of desaturation events when severely hypoxemic patients were excluded. But, a subsequent randomized control trial did not show any difference when compared with facial bag valve mask for preoxygenation pre intubation[28]. The RCT had included severe hypoxemic patients. A recent trial comparing HFNC during laryngoscopy with no supplemental oxygen also failed to show any difference in desaturation episodes. The role of HFNC in this setting is still not clear.
3. Immunocompromised patients with hypoxemic respiratory failure-retrospective studies in adults confirm feasibility and safety of HFNC in immunocompromised patients and demonstrate at least equipoise between HFNC, NIV and standard oxygen in this setting[29].

   Cardiogenic pulmonary edema, asthma, patients with do not intubate orders, oxygenation during bronchoscopy exam are other promising areas of application of HFNC which needs more studies to prove efficacy advantage over non invasive CPAP.

Conclusions

Current evidence suggests that HFNC is a well-tolerated and feasible respiratory support across different age groups and indications in the Pediatric ICU and Emergency Room. Available evidence suggests that it is not inferior to the alternate modes of noninvasive positive pressure ventilation and may have the advantage of more patient comfort and need for less pharmacological sedation. The initiation, escalation and weaning practices vary across different institutions and needs to be standardized. Well established local guidelines for initiation, monitoring and escalation and strict adherence will ensure the safety of its use in settings outside the critical care units, where there is a fear of late deterioration and delay in starting the appropriate respiratory support. It would be equally important to identify the nonresponders early, so that more appropriate modes of respiratory support are provided earlier rather than later. There is a need to focus on identifying additional indications where there is a definite advantage over noninvasive ventilation as a mode of respiratory support. Further information is also needed to establish its role in improving relevant outcomes like preventing intubation and decreasing ventilator free days in respiratory failure of various etiologies in children. We eagerly anticipate more studies establishing the utility in conditions like immunocompromised and asthma where there is a definite advantage of avoiding intubation.

Conflict of Interest: None
Source of Funding: None

References

1. Sreenan C, Lemke RP, Hudson-Mason a, Osiovich H. High-flow nasal cannulae in the management of apnea of prematurity: a comparison with conventional nasal continuous positive airway pressure. Pediatrics 2001;107:1081-3.
2. Lee JH, Rehder KJ, Williford L, Cheifetz IM, Turner D a. Use of high flow nasal cannula in critically ill infants, children, and adults: a critical review of the literature. Intensive Care Med 2012;39:247–57.
3. Milési C, Boubal M, Jacquot A, Baleine J, Durand S, Odena MP, et al. High-flow nasal cannula: recommendations for daily practice in pediatrics. Ann Intensive Care 2014;4:29.
4. Kubicka ZJ, Limauro J, Darnall R a. Heated, humidified high-flow nasal cannula therapy: yet another way to deliver continuous positive airway pressure? Pediatrics. 2008;121:82-8.
5. Hough JL, Pham TMT, Schibler A. Physiologic effect of high-flow nasal cannula in infants with bronchiolitis. Pediatr Crit Care Med 2014;15:e214-9.
6. Mayfield S, Bogossian F, O'Malley L, Schibler A. High-flow nasal cannula oxygen therapy for infants with bronchiolitis: Pilot study. J Paediatr Child Health 2014;50:373–8.
7. Dysart K, Miller TL, Wolfson MR, Shaffer TH. Research in high flow therapy: Mechanisms of action. Respiratory Medicine 2009. p. 1400–5.
8. Franklin D, Dalziel S, Schlapbach LJ, Babl FE, Oakley E, Craig SS, et al. Early high flow nasal cannula therapy in bronchiolitis, a prospective randomised control trial (protocol): A Paediatric Acute Respiratory Intervention Study (PARIS). BMC Pediatr 2015;15:183.
9. Sivieri EM, Gerdes JS, Abbasi S. Effect of HFNC flow rate, cannula size, and nares diameter on generated airway pressures: An in vitro study. Pediatr Pulmonol 2013;48:506-14.
10. Schibler A, Pham TMT, Dunster KR, Foster K, Barlow A, Gibbons K, et al. Reduced intubation rates for infants after introduction of high-flow nasal prong oxygen delivery. Intensive Care Med 2011;37:847-52.
11. Kelly GS, Simon HK, Sturm JJ. High-flow nasal cannula use in children with respiratory distress in the emergency department: predicting the need for subsequent intubation. Pediatr Emerg Care 2013;29:888-92.
12. Abboud PA, Roth PJ, Skiles CL, Stolfi A, Rowin ME. Predictors of failure in infants with viral bronchiolitis treated with high-flow, high-humidity nasal cannula therapy. Pediatr Crit Care Med 2012;13:1.
13. Jentzer J, Dezfulian C, Emlet L. High-Flow Oxygen through Nasal Cannula in Acute Hypoxemic Respiratory Failure: the FLORALI study. F1000Research 2016;41:8-11.
14. Wilkinson DJ, Andersen CC, O'Donnell C. High flow nasal cannula for respiratory support in preterm infants. Cochrane Database Syst Rev. 2016;(1):Cd006405.
15. Mayfield S, Jauncey-Cooke J, Hough JL, Schibler A, Gibbons K, Bogossian F. High-flow nasal cannula therapy for respiratory support in children. Cochrane database Syst Rev. 2014;3(3):CD009850.
16. Metge P, Grimaldi C, Hassid S, Thomachot L, Loundou A, Martin C, et al. Comparison of a high-flow humidified nasal cannula to nasal continuous positive airway pressure in children with acute bronchiolitis: Experience in a pediatric intensive care unit. Eur J Pediatr 2014;173:953-8.
17. Pham TMT, O'Malley L, Mayfield S, Martin S, Schibler A. The effect of high flow nasal cannula therapy on the work of breathing in infants with bronchiolitis. Pediatr Pulmonol. 2015;50:713-20.
18. Bueno Campaña M, Olivares Ortiz J, Notario Muñoz C, Rupérez Lucas M, Fernández Rincón A, Patiño Hernández O, et al. High flow therapy versus hypertonic saline in bronchiolitis: randomised controlled trial. Arch Dis Child 2014;99:511–5.
19. Ten Brink F, Duke T, Evans J. High-flow nasal prong oxygen therapy or nasopharyngeal continuous positive airway pressure for children with moderate-to-severe respiratory distress?*. Pediatr Crit Care Med 2013;14:e326–31.
20. Bressan S, Balzani M, Krauss B, Pettenazzo A, Zanconato S, Baraldi E. High-flow nasal cannula oxygen for bronchiolitis in a pediatric ward: A pilot study. Eur J Pediatr 2013;172:1649-56.
21. Schlapbach LJ, Schaefer J, Brady AM, Mayfield S, Schibler A. High-flow nasal cannula (HFNC) support in interhospital transport of critically ill children. Intensive Care Med 2014;40:592-9.
22. Testa G, Iodice F, Ricci Z, Vitale V, De Razza F, Haiberger R, et al. Comparative evaluation of high-flow nasal cannula and conventional oxygen therapy in paediatric cardiac surgical patients: a randomized controlled trial. Interact Cardiovasc Thorac Surg 2014;19:456-61.
23. Joseph L, Goldberg S, Shitrit M, Picard E. High-flow nasal cannula therapy for obstructive sleep apnea in children. J Clin Sleep Med. American Academy of Sleep Medicine; 2015;11:1007–10.
24. Kang BJ, Koh Y, Lim CM, Huh JW, Baek S, Han M, et al. Failure of high-flow nasal cannula therapy may delay intubation and increase mortality. Intensive Care Med. 2015;41:623–32.
25. Papazian L, Corley A, Hess D, Fraser JF, Frat JP, Guitton C, et al. Use of high-flow nasal cannula oxygenation in ICU adults: a narrative review. Intensive Care Medicine 2016;42:1336-49.

26. Rittayamai N, Tscheikuna J, Rujiwit P. High-Flow Nasal Cannula Versus Conventional Oxygen Therapy After Endotracheal Extubation: A Randomized Crossover Physiologic Study. Respir Care 2014;59:485-90.
27. Miguel-Montanes R, Hajage D, Messika J, Bertrand F, Gaudry S, Rafat C, et al. Use of High-Flow Nasal Cannula Oxygen Therapy to Prevent Desaturation During Tracheal Intubation of Intensive Care Patients With Mild-to-Moderate Hypoxemia. Crit Care Med 2014;43:1–10.
28. Vourc'h M¸ Asfar P, Volteau C, Bachoumas K, Clavieras N, Egreteau PY, et al. High-flow nasal cannula oxygen during endotracheal intubation in hypoxemic patients: a randomized controlled clinical trial. Intensive Care Med 2015;41:1538-48.
29. Nishimura M. High-flow nasal cannula oxygen therapy in adults. J Intensive Care 2015;3:15.

How to cite this article: Kesavan S, Ramachandran B. Humidified High-flow Nasal Cannula Oxygen Therapy in children- a narrative review. J Pediatr Crit Care 2016;3(4):29-34

How to cite this URL: Kesavan S, Ramachandran B. Humidified High-flow Nasal Cannula Oxygen Therapy in children- a narrative review. J Pediatr Crit Care 2016;3(4):29-34. Available from: http://www.journalofpediatriccriticalcare.com/userfiles/2016/0304-jpcc-oct-dec-2016/JPCC0304004.html