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Humidified High Flow Nasal Cannula (HHFNC) Oxygen Therapy: A guide for Ward and Emergency Department Based use in Children <24 months with Acute Viral Bronchiolitis

Link to HHFNC Algorithm

Aim

The aim of this document is to provide a guide for the application of HHFNC to patients with acute viral bronchiolitis on the wards or in the emergency department.

Definition of terms

CBG – Capillary Blood Gas
CXR – Chest X-Ray
ED – Emergency Department
FiO_2 – Fraction of Inspired Oxygen
HR – Heart Rate
HHFNC – Humidified High Flow Nasal Cannula
NGT – Nasogastric Tube
PICU – Paediatric Intensive Care Unit
PEWS – Paediatric Early Warning System
PEEP – Peak End Expiratory Pressure
RR – Respiratory Rate

Target Patient Population

This guideline applies to infants and children with moderate to severe respiratory distress with a clinical diagnosis of acute viral bronchiolitis who meet the criteria as outlined below for treatment on the wards or in the ED with HHFNC.

Target Users

This guide is directed at health-care professionals engaged in the care of infants and children <24 months in acute respiratory distress due to viral bronchiolitis who may benefit from treatment with HHFNC O_2. Although many aspects of this guideline may be extrapolated for use across all paediatric hospital settings in Ireland, this guideline is written specifically with the tertiary paediatric hospitals in mind. HHFNC is a medically ordered mode of respiratory support and should only be initiated by medical and nursing staff with knowledge and experience in its use.

Introduction

Humidified high flow nasal cannula (HHFNC) therapy is a relatively new therapy for respiratory distress that offers non-invasive respiratory support through the delivery of high flow, humidified oxygen at various concentrations. Some studies have demonstrated that the appropriate use of HHFNC in infants and children with respiratory distress can reduce the need for invasive ventilation[iii]. It is proposed that

HHFNC reduces the work of breathing and improved efficacy of ventilation through several mechanisms, many of which are still under investigation:

- Improved mechanics by supplying adequately warmed and humidified gas: Studies have shown that providing gas that is warmed and humidified results in a significant decrease in pulmonary conductance and compliance[iii].

- Reduced inspiratory work of breathing by providing increased airflow: The effect of HHFNC on inspiration is to provide nasopharyngeal gas flows that match or exceed a patient's peak inspiratory flow – this alters the inspiratory resistance and results in decreased work of breathing[iv].

- Reduced metabolic cost of gas conditioning: Delivery of high flow gas without warming or humidification can result in the drying of nasal passages, mucosal injury, impaired secretion clearance and patient discomfort. When oxygen is delivered via HHFNC, it is heated to near body temperature and humidified to almost 100% of relative humidity. This then allows the gas to be delivered at high flow rates without causing local damage/irritation[v]. By conditioning the gas to optimal temperature and humidity prior to its delivery, the metabolic demand on the body to perform the same tasks is felt to be greatly reduced[vi].

- Washout of nasopharyngeal dead space: The nasopharyngeal dead space contains end expiratory gas at the beginning of inspiration. Whilst this heats and humidifies inspired air, it reduces the efficacy of gas exchange. By washing out this dead space, HHFNC improves alveolar ventilation and also facilitates carbon dioxide removal[vii].

- Provision of distending pressure: The nasopharynx also contributes to upper airway resistance. It is hypothesised that HHFNC contributes to reducing upper airway resistance by providing positive pressure that can help to stent the upper airway. It is important to note that the positive pressure produced by HHFNC cannot be quantified or regulated in the same fashion as CPAP as it is affected by flow rate, mouth position (open/closed), patient weight and diameter of nasal cannulae[viii],[ix].

Available evidence:

HHFNC is a widely used method of providing respiratory support for acute and chronic respiratory pathologies across all age groups. Small observational and physiological studies demonstrate that HHFNC results in decreased work of breathing, decreased rates of intubation and improved oxygenation and that it is overall a well-tolerated therapy. At present, there are no published international guidelines (e.g. British Thoracic Society) examining the role of HHFNC for children with acute respiratory distress. Most available recommendations are based on extrapolations from small studies. The PARIS trial was a multicentre, randomised-controlled trial that specifically looked at the use of HHFNC in infants with bronchiolitis and demonstrated that it was a safe and effective therapy that can prevent escalation of care in this patient cohort to a PICU setting and/or invasive ventilation[x].

Indications

- The management of acute respiratory distress in infants on the wards or in the ED due to acute viral bronchiolitis.
- Special consideration must be given to patients with underlying cardiac defects prior to commencement of HHFNC (Please see special consideration section).
  Children with significant respiratory distress due to other respiratory conditions not effectively managed with low flow oxygen may benefit from a trial of HHFNC on the advice of the supervising consultant, these should be approached and managed on a case by case basis.

Contraindications

- Blocked nasal passages e.g. choanal atresia
- Acute upper airway obstruction
- Trauma
- Injury to the nasopharynx
- Air leak (e.g. pneumothorax)[xi]
- Life threatening hypoxia

Complications

As outlined above, HHFNC therapy generates positive pressures in the nasopharynx which cannot be accurately monitored. In a highly compliant system, a small increase in pressure delivers a much higher gas volume, which can lead to the development of pneumothorax secondary to both barotrauma[xii] and volutrauma[xiii] . High flow rates of gas delivery via nasal cannula can result in alveolar over-distension and cause air leak syndromes. Case reports exist of serious air leak syndrome associated with HHFNC therapy[xiv] . HHFNC is also more labour intensive than conventional low-flow oxygen and requires more resources to utilise. Complications to observe for while using HHFNC are as follows:

- Gastric distension
- Pneumothorax/other air leak
- Local skin and/or mucosal pressure injury
- Blocked HHFNC due to secretions

Initiation:

(Please see algorithm for quick reference)

- HHFNC may be considered appropriate when a child with acute viral bronchiolitis displays persistent signs of moderate to severe respiratory distress despite conventional therapy e.g. low flow nasal cannula oxygen, normal saline or hypertonic saline nebulisers.
- The decision to initiate HHFNC therapy may be made by a medical / emergency department registrar with input from the Consultant Paediatrician / Consultant in Paediatric Emergency Medicine on call if needed.
- **If there is no improvement as demonstrated by clinical signs of stabilisation (outlined below) within two hours of commencement of HHFNC the Medical Consultant / Consultant in Paediatric Emergency Medicine must be informed of the patient.**
- It is not necessary to make the PICU / anaesthetic team on call aware of all patients commencing on HHFNC on either the wards or in the ED.
- **Commencement of HHFNC should not mitigate the need for PICU / anaesthetic review for children with severe respiratory distress and/or who are deteriorating.**
- For the initiation of HHFNC in patients with underlying congenital cardiac defects please see special considerations below.

Commencing Therapy:

- **CXR and venous/capillary blood gas are not routinely required but may be considered if clinically indicated.**
- Low threshold for insertion of NGT and aspiration, particularly in smaller or at risk infants. NGT may not be necessary for larger infants/toddlers.
- A follow-up review by a medical registrar **must** take place within two hours of commencement of HHFNC therapy to ensure improvement and stabilisation.
- The high flow system should be commenced at the settings outlined in the table below with appropriately sized nasal cannula[xv].

- HHFNC therapy should be escalated as outlined in Table 1 below at or before 2 hours following initiation of therapy, following medical registrar review if:[xvi]
    - Respiratory distress/hypoxaemia persist.
    - SpO_2 persistently< 92%.
    - Any increase in the PEWS Score from the initial parameters at the commencement of HHFNC therapy.
- If the HHFNC is escalated appropriately, they should display signs of stabilisation two hours following initiation or escalation of HHFNC therapy in line with the table below.
- If there is no improvement despite escalation as per the table, the patient can be considered to have failed HHFNC and PICU / anaesthetics review is warranted and admission to PICU should be considered for alternative respiratory support after discussion with Consultant Paediatrician / Consultant in Paediatric Emergency Medicine

Transfer of Patients on HHFNC:

Ensure that the High Flow delivery system connected correctly to a UPS system that is fully charged before transfer. As there is a limited battery life (approximately 20 minutes) it is imperative to avoid unnecessary delays during transfer.

Table 1:

Guide for Initiation and Escalation of HHFNC Therapy:

	Children with bronchiolitis <24 months
Initial settings*	**2L/kg/min with FiO_2 titrated to maintain $SpO_2 \geq 92\%$**
Escalation of care	**If > 50% FiO_2 required to maintain SpO_2 > 92% contact medical consultant on call and refer to PICU**
Maximum Flow**	**30L/min *** **

Referral to PICU should be considered at any escalation point if the patient is clinically deteriorating and/or showing no signs of stabilisation.

****** ***Flow rate can be escalated above the maximum rate at the discretion of a PICU Consultant / Consultant in Paediatric Emergency Medicine / Consultant Paediatrician.***

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******* ***See attached sizing guidelines and please note recent introduction of Optiflow XXL nasal cannula for larger children can administer up to 50L/min flow. If child's nares are too small for this size, they are restricted to 25L/min with Optiflow XL size nasal cannula.***

Additional Medical Interventions:

These can be considered by the medical team alongside the use of HHFNC to optimise patient comfort and stability. ***The use of sedatives (including chloral hydrate) or diuretics must be discussed with the Consultant Paediatrician and / or PICU consultant on call.***

- Analgesia and antipyretics
- Diuretics, if concern for fluid overload
- Sedatives e.g. chloral hydrate
- Antibiotics if high suspicion of secondary bacterial infection

Clinical Signs of Stabilisation:

- Within two hours *clinical signs of stabilisation* should be seen and can be measured according to the following parameters[xviixviii]:

    - FiO_2 required to maintain the SpO_2 in the target range should decrease to <40%
    - Heart rate should reduce by 20% or be within the normal range for age.
    - Respiratory rate should reduce by 20% or be within the normal range for age.
    - Clinical signs of respiratory distress should improve (e.g. recessions, nasal flaring, tracheal tug).
    - Consider a repeat CBG/VBG based on clinical scenario.

Acute Deterioration on HHFNC:

- Urgent medical review required if any of the following occur:
    - Sudden worsening of respiratory distress and/or SpO_2 - urgent CXR should be performed to exclude a pneumothorax.
    - Recurrent/frequent apnoea and or bradycardia.
    - Persistent hypoxaemia despite adequate escalation of FiO_2/Flow.
    - Sudden deterioration in patient's overall condition.

Nursing Care of Patient on HHFNC

All nursing staff must work within the scope of their professional practice; it is their responsibility to know the limits of their practice relating to the care of a child requiring HHFNC and to seek advice from a senior nursing colleague and/or medical staff to ensure the best outcome for the patient. For more detailed instructions, please refer to nursing care plan.

- Ensure appropriate positioning to optimise air entry (semi-upright).
- Perform any required investigations e.g. NPA / nasal swab / throat swabs prior to application of HHFNC where possible.
- Consider insertion of an NGT at time of HHNFC application if there is significant abdominal distension contributing to distress or inability of the child to adequately feed.
- Once patient has stabilised on high flow therapy, they should be assessed as to whether or not they can feed (either PO or via NGT) by medical staff.
- If inserted, NGT should be aspirated every 2 – 4 hours.
- Comfort feeds orally may be tolerated but most patients will require NGT feeding.
- If infants have not clinically stabilised and therapy is being escalated they should be commenced on maintenance IV fluids, made NPO and an NGT inserted (if not already in place) and aspirated.
- Minimal handling.
- Oral and nasal care should be performed 4 hourly, to ensure that nostrils do not occlude.

    - When fitting the nasal cannula, there should always be a visible gap around the cannula when fitted in the nares.
    - Confirm that nasal cannula remains in the correct position and that there is no skin injury due to excessive pressure.
    - Gentle suction may be needed to keep nostrils patent.
    - Ensure appropriately sized cannula in use (see pictorial diagram).

Patient monitoring

- Continuous monitoring of SpO_2 and HR via pulse oximetry with hourly recording.
- Observations must be documented clearly and include the flow of gas (air/oxygen) (L/min), the FiO_2 and the humidifier temperature.
- In the first two hours of therapy, monitor the patient every 15 minutes for a response in the following parameters: RR, HR, SpO_2, respiratory distress and work of breathing – until stabilisation in parameters noted.
- Once vital signs have stabilised – observations can be monitored less frequently at discretion of medical and nursing staff in accordance with PEWS score.

Weaning therapy

Consideration of weaning of HHFNC can be made when the patient is no longer felt to be in moderate-severe respiratory distress. Weaning can be performed as outlined below:

- Wean back down to a flow rate of 2L/kg/min if the patient had been escalated above this flow rate after initiation of HHFNC.
- **There is no need to wean the flow rate below 2L/kg/min[xix] nor is there any need for a prolonged weaning process in general.**
- Wean FiO_2 down to 21% by increments of 10% (i.e. FiO_2 40% to wean to FiO_2 30%) to maintain SpO_2 >92% (reviewing every 2 – 4 hours)
- Monitor and document SpO_2, RR, HR and respiratory distress (if any) after each change in FiO_2.
- Inform senior nursing and medical staff if there is any deterioration in respiratory/cardiovascular status – therapy may need to be increased.
- Once the child is stable, is on a flow rate of 2L/kg/min and in a FiO_2 of 21% for four hours standard low flow nasal cannula oxygen should be used[xx].
- Alternative weaning instructions are at the discretion of the medical team.

Special Considerations

COVID-19

If a patient presents in respiratory distress and it is felt that HHFNC is necessary to optimise their management, full Personal Protective Equipment must be worn if they are a suspected or a confirmed case of COVID 19. Full adherence to local infection control policies must be also be observed.

Respiratory co-morbidities

Please note that the use of HHFNC in children with respiratory co-morbidities such as lung disease of prematurity, pulmonary hypoplasia, sleep disordered breathing or asthma is outside the scope of this guideline.

Use of nebulised therapies via HHFNC circuit.
If nebulised treatments are prescribed by the clinical teams, the Aerogen solo nebuliser units are now compatible and used with HHFNC so that therapy is not disrupted. These are currently used throughout the wards except in ED in CHI at TS.

Cardiology:

Certain patients with congenital cardiac defects may be suitable candidates for HHFNC therapy[xxi]. This can only be commenced in this population following discussion with the consultant paediatric cardiologist on-call after any other necessary investigations/treatments required have been performed. Consideration should also be given to informing the PICU team on call.

Target SpO_2 levels will be patient specific in this population and must be clearly documented prior to initiation of therapy. Over-oxygenation can be a risk in patients with underlying cyanotic defects so maximum SpO_2 levels tolerated must also be determined with review of HHFNC if this is exceeded (Usually target range for SpO_2 of 75 – 85% in cyanotic cardiac disease with balanced circulation)[xxii].

HHFNC O_2 can only be used on Cardiac patients who are on the Children's Heart Centre or in PICU as an experienced nurse is required.

- FiO_2 is commenced at 0.21 (21%)
- Flow is titrated by weight as with any other patient
- If FiO_2 between 0.21 and 0.3 (30%) is required patient should again be discussed with Cardiology team and PICU review considered.
- If FiO_2 greater than 0.3 (30%) required patient should be reviewed by PICU.[xxiii]

Companion Documents

Optiflow Sizing Guide

Useful Links

1. Standard Operating Procedure for HHFNC
2. https://pch.health.wa.gov.au/For-health-professionals/Clinical-PracticeGuidelines/Humidified-High-Flow-Nasal-Cannula-Therapy
3. https://www.rch.org.au/rchcpg/hospital_clinical_guideline_index/High_flow_nasal_prong_(HFNP)_therapy/
4. http://www.rch.org.au/rchcpg/hospital_clinical_guideline_index/Oxygen_delivery/
5. https://www.nice.org.uk/researchrecommendation/high-flow-humidified-oxygen-andoxygen-what-is-the-clinical-and-cost-effectiveness-of-high-flow-humidified-oxygenversus-standard-supplemental-oxygen

Airvo2 smartphone App

References

[i]High Flow nasal Cannulae Therapy in Infants with Bronchiolitis. McKiernan C et al. Journal of Pediatrics 10.039 2009

[ii] Use of High Flow Nasal Cannula Support in the Emergency Department reduces the need for Intubation in Pediatric Acute Respiratory Insufficiency. Wing R et al. Pediatric Emergency Care, Vol 28, No 11, Nov 2012.

[iii] Research in high flow therapy: Mechanisms of Action. K Dysart, T Millar, M Wolfson, T Shaffer. Respiratory Medicine (2009) 103, 1400 – 1405

[iv]Effort of Breathing in children Receiving High-Flow Nasal Cannula. Rubin S et al. Pediatric Critical Care Medicine Jan 2014 Vol 15 No 1.

[v] High flow nasal cannula: recommendations for daily practice in pediatrics. Milesi C et al. Annals of Intensive Care 2014, 4:29.

[vi]The evidence for high flow nasal cannula devices in infants. HaqA et al. Paediatric Respiratory Reviews 15 (2014) 124-134.

[vii]The evidence for high flow nasal cannula devices in infants. HaqA et al. Paediatric Respiratory Reviews 15 (2014) 124-134.

[viii] Nasopharyngeal Airway Pressures in Bronchiolitis Patients Treated with High-Flow Nasal Cannula Oxygen Therapy. Arora B et al. Pediatric Emergency Care, Vol 28, No 11, Nov 2012.

[ix] Evidence of HFNC flow rate, Cannula Size and Nares Diameter on Generated Airway pressures: An In Vitro Study. Sivieri E, Gerdes J, Abbasi S. Pediatric Pulmonology 48:506-514 (2013)

[x] A Randomised Trial of High-Flow Oxygen Therapy in Infants with Bronchiolitis: PARIS Trial. Franklin D et al, N Engl J Med 2018;378:1121-31.

[xi]Serious Air Leak Syndrome Complicating High-Flow Nasal Cannula therapy: A report of 3 Cases. Hegde S, Prodhan P. Pediatrics 2013;131.

[xii] Alveolar overdistension is an important mechanism of persistent lung damage following severe protracted ARDS. Finfer S, Rocker G. Anaesth Intensive Care. 1996;24(5):569–573

[xiii] Inadvertent administration of positive end-distending pressure during nasal cannula flow. Locke RG et al. Pediatrics. 1993;91(1):135–138

[xiv]Serious Air Leak Syndrome Complicating High-Flow Nasal Cannula therapy: A report of 3 Cases. Hegde S, Prodhan P. Pediatrics 2013;131.

[xv]Heated humidified high-flow nasal cannula therapy in children. Hutchings F, Hilliard TN, Davis PJ. Arch dis Child 2014;0:1-5

[xvi]Humidified High Flow Nasal Cannula Therapy for Children, Clinical Practice Guideline, Princess Margaret Hospital for Children.

[xvii]High-flow nasal cannula oxygen therapy for infants with Bronchiolitis: Pilot Study. Mayfield S, Bogossia N, O'Mally L, Schibler A. Journal of Paediatrics and Child Healthn 50 (2014) 373-378.

[xviii]High Flow Nasal Prong Therapy, Clinical Nursing Guidelines, The Royal Children's Hospital Melbourne.

[xix]Humidified High Flow Nasal Cannula Therapy for Children, Clinical Practice Guideline, Princess Margaret Hospital for Children.

[xx] A Randomised Trial of High-Flow Oxygen Therapy in Infants with Bronchiolitis: PARIS Trial. Franklin D et al, N Engl J Med 2018;378:1121-31.

[xxi]Comparative evaluation of high-flow nasal cannula and conventional oxygen therapy in paediatric cardiac surgical patients : a randomised control trial. Testa G et al. Interactive Cardiovascular and Thoracic Surgery 19 (2014) 456 – 461.

[xxii]High Flow Nasal Prong Therapy, Clinical Nursing Guidelines, The Royal Children's Hospital Melbourne.

[xxiii]High Flow Nasal Prong Therapy, Clinical Nursing Guidelines, The Royal Children's Hospital Melbourne.

[31]Yoder BA, Stoddard RA, Li M, King J, Dirnberger DR, Abbasi S. Heated, humidified high-flow nasal cannula versus nasal CPAP for respiratory support in neonates. Pediatrics 2013 May;131(5):e1482–90.