

Is there a role for humidified heated high-flow nasal cannula therapy in paediatric emergency departments?

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► Additional material is published online only. To view, please visit the journal online (<http://dx.doi.org/10.1136/emmermed-2015-204914>).

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Received 16 April 2015

Revised 1 December 2015

Accepted 7 December 2015

Published Online First

4 January 2016

ABSTRACT

Background Humidified heated high-flow nasal cannula (HFNC) therapy is a potentially useful form of non-invasive respiratory support for children with moderate respiratory distress and/or hypoxaemia. No prospective data support its use in the paediatric emergency department (ED). We introduced HFNC therapy into a paediatric ED and evaluated its use and failure rates.

Methods Prospective observational study of all patients presenting to the Royal Children's Hospital, Australia, who received HFNC therapy between April 2013 and September 2013 (one southern hemisphere winter season). We assessed demographics, indications, failure rate, predictors of failure and adverse events.

Results 71 patients commenced HFNC therapy in ED over the study period. The median age was 9 months. The most common indication was bronchiolitis (49/71; 69%). Five (7%) of the patients failed HFNC and were escalated to other forms of respiratory support in ED, four to nasal continuous positive airway pressure and one required intubation. A further 21 (32%) failed HFNC therapy after intensive care unit (ICU) admission, giving a total failure of 28 (39%). There were no serious adverse events in ED, and one child with asthma developed air leak syndrome after transfer to the ICU.

Conclusions HFNC therapy may have a role in the paediatric ED as an easily administered and well tolerated form of non-invasive respiratory support, but about one-third of patients required escalation to a higher level of respiratory support. Further studies should assess the safety profile of HFNC in larger series, and define the role of HFNC in key respiratory conditions compared with other possible interventions.

INTRODUCTION

Respiratory illness is the single most common reason for hospitalisation in children, and requirement for respiratory support is the most common indication for paediatric intensive care unit (PICU) admission overall.¹ Therefore, there is considerable potential benefit from a non-invasive form of respiratory support that is easy to apply and care for, and is tolerable to patients, such as high-flow nasal cannula therapy (HFNC therapy). The prototypical illness where this might apply is in infants with bronchiolitis, where medical therapies have not been shown to be effective in reducing symptoms or altering the disease course.^{2,3}

HFNC therapy was first described as a non-invasive method for delivering positive airway pressure in preterm neonates.⁴ It has subsequently been applied to a broader patient group with moderate to severe respiratory distress or hypoxaemia not

Key messages

What is already known on this subject?

- High-flow nasal cannula (HFNC) therapy provides some respiratory support in the form of positive airway pressure, gas conditioning and titratable fraction of inspired oxygen.
- HFNC therapy is associated with reduced intubation rates for acute respiratory failure in children in the paediatric intensive care unit.

What might this study add?

- In this prospective study of 71 children receiving high-flow nasal cannula (HFNC) in a paediatric ED, approximately one-third commenced on HFNC received escalation of respiratory support in the ED or during hospitalisation.

relieved by standard oxygen therapy. Possible indications include children with bronchiolitis, pneumonia, congestive cardiac failure, neuromuscular disease, apnoea of prematurity and as respiratory support following extubation from mechanical ventilation or weaning from other forms of non-invasive respiratory support.⁵ HFNC is thought to be of benefit in acute respiratory failure by decreasing upper airway resistance, washing out anatomical dead space, reducing the metabolic cost of gas conditioning and delivering variable and unmeasured positive airway pressure.^{6,7} It also allows the administration of variable fraction of inspired oxygen (FiO₂) by minimising entrainment of room air. Flow rates described as constituting high flow are variable, ranging from 1 to 2 L/kg/min, with some evidence that higher flow rates deliver higher positive airway pressure,^{8,9} and that air leak around the nares and mouth opening significantly affect delivered pressure.¹⁰ There is currently limited evidence to support the efficacy and safety of HFNC for its use as a form of respiratory support in the treatment of the variety of indications for which it is currently used.⁷ As with any form of positive airway pressure, HFNC may result in the development of air leak syndromes and may decrease venous return and thus cardiac output.¹¹ The major perceived benefits of HFNC over other forms of non-invasive respiratory support are its ease of application and level of nursing care required, and its patient tolerability without requiring sedation in the majority of patients compared with nasal continuous positive airway pressure (CPAP).¹² The use of intermediate flow rates



To cite: Long E, Babl FE, Duke T. *Emerg Med J* 2016;**33**:386–389.



(below 1 L/kg/min), and the delivery of humidified oxygen at conventional (low) flow rates or high flow rates through face masks do not provide any positive airway pressure and therefore do not constitute HFNC therapy in this context.

Randomised controlled trials in preterm infants indicate that HFNC therapy has similar efficacy to nasal CPAP as an initial form of respiratory support¹³ and as postextubation respiratory support.¹⁴ One multicentred prospective randomised trial comparing HFNC, bilevel positive airway pressure (BiPAP) and non-rebreather face mask oxygen for acute hypoxaemic respiratory failure in adults found no significant difference in subsequent intubation rate.¹⁵ There have been no randomised trials of HFNC therapy in any other setting. Observational studies suggest that HFNC therapy, when introduced to PICUs, is associated with a reduction in intubation rate, that it is safe, and associated with failure rates of around 25%–30%.^{5 16} Emergency department (ED) data on the use of HFNC therapy are limited. Retrospective observational data from before and after the introduction of HFNC therapy in the paediatric ED did not show a reduction in intubation rate for children with acute respiratory failure, however the ICU admission rate was increased.¹⁷

We introduced HFNC therapy in the paediatric ED under hospital-wide guidelines for its use over a 6-month trial phase. As this has not been previously described, we documented the patient demographics, indications, failure rate and adverse events prospectively over this introductory period. We assessed if patients who failed HFNC could be predicted based on response to therapy within 2 h of initiation.

METHODS

We undertook a prospective evaluation of patients receiving HFNC therapy during the first 6 months after its introduction in the paediatric ED of the Royal Children's Hospital (RCH), Melbourne, Australia. The RCH ED has over 85 000 presentations annually, approximately 1400 diagnosed with bronchiolitis, of whom 580 (40%) are admitted to hospital and 50 (3.5%) to ICU. The study was approved by the hospital's Human Research and Ethics Committee.

Following the introduction of HFNC therapy in the ICU at RCH, a guideline for standardised set-up and delivery was developed (see online supplementary appendix 1).⁵ The guideline refers to a single proprietary HFNC delivery system that is used in our institution, though multiple other delivery systems exist.¹⁸ Equipment and training were provided to ED staff prior to introduction of HFNC. The flow rate used during the study period was 2 L/kg/min for the first 10 kg, then 0.5 L/kg/min for every kilogram thereafter. Indications for use of HFNC were broadly defined as moderate to severe respiratory distress where increased work of breathing or hypoxaemia was not relieved by standard oxygen therapy.

Study patients were identified prospectively by their treating clinician, who completed a clinical report form at the time of patient encounter (see online supplementary appendix 2). Patients of any age who were started on HFNC therapy in ED were included. There were no exclusions. Patients age, weight, diagnosis, comorbidities, vital signs before starting HFNC (HR, RR and oxygen saturations (SpO₂)), flow rate and fraction of inspired oxygen (FiO₂) on initiation, vital signs and FiO₂ 2 h after initiation, sedation requirement, outcome and adverse events were recorded by the ED treating clinician. Missing data points were obtained from the patient's records or through direct contact with the treating clinician. The ED electronic record was searched weekly to ensure that all patients started on

HFNC were captured, and the ICU admission log was cross-referenced to ensure that no patients were missed (at the time of the study all children admitted on HFNC were managed in ICU).

Failure of HFNC therapy was defined as escalation of respiratory support to another form of non-invasive ventilation (nasal CPAP) or BiPAP or invasive ventilation within 24 h of initiation of HFNC therapy. Normalisation of vital signs was defined according to hospital-wide medical emergency team criteria.¹⁹

Data were entered into a Microsoft Excel 2010 (Microsoft, Redmond, Washington, USA) database. Descriptive statistics were used for key proportions.

RESULTS

Over the 6-month study period, 71 patients were started on HFNC therapy. Sixty-nine (97%) of the patients received flow rates according to the guidelines. The median age was 9 months, and the most common diagnosis was bronchiolitis (table 1). Comorbidities were uncommon.

Patients receiving HFNC were transferred to ICU for ongoing management (table 2). Failure of HFNC therapy in ED occurred in five patients (7%). Four were escalated to nasal CPAP in ED, and one was intubated in ED. Following admission to PICU, 16 (23%) patients were escalated to nasal CPAP and seven (10%) intubated. Overall 28 children required escalation of respiratory support, giving a failure rate of 39%.

Twenty-four patients (34%) were treated with chloral hydrate for sedation following the initiation of HFNC therapy.

There were no adverse events in ED except three patients developed abdominal distension. After transfer to ICU one patient on HFNC developed air leak syndrome. This occurred in a 4-year-old girl with severe asthma treated with HFNC at a flow rate of 40 L/min for 10 h. Bilateral pneumothoraces, pneumomediastinum, pneumopericardium and subcutaneous emphysema developed, requiring bilateral chest drain insertion and intubation.

DISCUSSION

In this prospective study of HFNC as a method for providing respiratory support we found it to be well tolerated and easily administered. Overall 39% of patients failed HFNC therapy.

Two retrospective studies have examined the use of HFNC in the paediatric ED. The first compared intubation rates in ED before and after the introduction of HFNC as a form of respiratory support.¹⁷ The authors found a significant reduction in ED intubation rates after the introduction of HFNC therapy. Total intubation rates over the study period (ED and PICU combined) did not change, and the reduction in intubation rates in ED was associated with a concomitant increase in intubation rates during ongoing care in PICU. Though only 7% patients in our study failed HFNC in ED, 28% went on to fail HFNC therapy during their subsequent hospitalisation. PICU admission rates have been variably affected after the introduction of HFNC therapy in EDs or on wards.^{17 20} Clear predictors of failure of HFNC and wards trained and equipped to manage children successfully initiated on HFNC seem to be critical in reducing PICU admission rates following the introduction of HFNC. Observational studies performed in PICU support the notion that HFNC therapy reduces intubation rates for acute respiratory compromise,^{16 21} though to date no randomised comparison of HFNC with other forms of respiratory support have been performed outside neonatal ICU. The increase in PICU admission rates should HFNC be introduced in ED raises the issue of disposition of patients on HFNC therapy. Should

Table 1 Demographic information, indication and initial vital signs for patients treated with HFNC therapy in the ED

	All patients (n=71)	Successfully initiated on HFNC (n=43)	Failed HFNC (n=28)
Age (months) (median, IQR)	9 (3–18)	12 (7–20)	8 (4–15)
Male n (%)	41 (58)	23 (53)	18 (64)
Comorbidity n (%)			
Nil	62 (87)	37 (86)	25 (89)
Chronic lung disease	4 (6)	3 (7)	1 (4)
Congenital heart disease	3 (4)	3 (7)	0 (0)
Cerebral palsy	2 (3)	0 (0)	2 (7)
Indication for HFNC n (%)			
Bronchiolitis	49 (69)	28 (65)	21 (75)
Acute lower respiratory tract infection	17 (24)	11 (26)	6 (21)
Asthma	2 (3)	1 (2)	1 (3)
Sepsis	1 (1)	1 (2)	0 (0)
Apnoea	1 (1)	1 (2)	0 (0)
Cardiac disease	1 (1)	1 (2)	0 (0)
Initial vital signs			
HR; median (IQR)	167 (152–182)	164 (153–179)	172 (150–185)
RR; median (IQR)	63 (54–70)	60 (52–65)	68 (56–76)
Temperature (°C); median (IQR)	37.5 (37.2–37.9)	37.5 (37.3–37.9)	37.5 (37.2–39.9)
Oxygen saturation (%); median (IQR)	97 (96–99)	97 (96–98)	97 (96–99)
Vital signs 2 h after initiation of HFNC			
HR; median (IQR)	151 (139–167))	144 (136–159)	157 (151–170)
RR; median (IQR)	58 (52–65)	46 (41–50)	61 (55–67)
Temperature (°C); median (IQR)	37.3 (37.1–37.8)	37.3 (37.0–37.8)	37.4 (37.1–37.8)
Oxygen saturation (%); median (IQR)	96 (94–99)	97 (95–98)	96 (94–98)

HFNC, high-flow nasal cannula.

hospital wards not be trained, equipped and supported to deliver HFNC, its introduction to ED may increase PICU admission rates. At the time our study took place, all patients initiated on HFNC therapy in ED were transferred to PICU for ongoing care. With limited evidence for safety outside of critical care areas,²² ongoing HFNC therapy has subsequently been trialled successfully on our hospital wards.

The second retrospective study of HFNC therapy in the paediatric ED looked at predictors of failure of HFNC therapy.²³ The authors found that tachypnoea (>90th percentile for age), an initial pCO₂ >50 mm Hg and an initial venous pH of <7.30 were associated with failure of HFNC therapy. One or more of these predictors were present in 23 of the 28 patients (82%) who failed HFNC overall in our study. Twenty-two of

the 43 patients (51%) who did not fail HFNC therapy had continued abnormalities of one or more of these parameters at 2 h. Additional studies in the PICU environment have found lower initial RR, high initial pCO₂ and failure of RR to improve/saturations to improve with HFNC to be predictive of failure.²⁴

The overall failure rate for HFNC therapy in the ICU has been reported as around 30%, with 5%–10% requiring escalation to invasive ventilation.^{5 16} In our study, 7% patients failed HFNC therapy in ED, and 32% subsequently failed HFNC therapy in PICU. Overall the need for endotracheal intubation was 11%. A 39% total failure rate is similar overall to those reported from the ICU setting.

The adverse event rate in our study was low, with no serious adverse events occurring in ED. During ongoing care in PICU, one patient developed an air leak syndrome. It should be noted that this patient was being treated for severe asthma, where air leak syndrome has been reported even in patients receiving no respiratory support.²⁵ Additionally, though air leak syndrome has been reported at low-flow rates,²⁶ the flow rate being delivered during this adverse event was higher than that recommended in our current clinical guideline. In this small, non-comparative, single centred observational study, it is difficult to draw conclusions regarding the relative safety of HFNC compared with other forms of non-invasive respiratory support. Nevertheless, an index of suspicion should exist for the potential development of air leak syndromes in patients treated with HFNC.

Limitations

Though every effort was made to identify all patients initiated on HFNC during the study period, there may have been some patients missed who rapidly deteriorated to invasive respiratory

Table 2 Disposition and highest level of respiratory support during hospitalisation in patients initiated on HFNC therapy in the ED

Outcome following initiation of HFNC n (%)	
Transferred to PICU on HFNC	64 (90)
Escalation to nCPAP in ED	3 (4)
Escalation to intubation in ED	1 (1)
HFNC not tolerated	2 (3)
Weaned to low-flow oxygen in ED	1 (1)
Highest level of respiratory support during admission n (%)	
HFNC	43 (61)
nCPAP	20 (28)
ETT	8 (11)

ETT, endotracheal tube; HFNC, high-flow nasal cannula; nCPAP, nasal continuous positive airway pressure; PICU, paediatric intensive care unit.

support after a short trial of HFNC. Our study was observational and non-comparative in nature and therefore could not be used to comment on the efficacy of HFNC therapy or the flow rate that should optimally be used.

CONCLUSION

HFNC oxygen therapy appears to be a feasible method for delivering respiratory support, which can be initiated in the paediatric ED. Ongoing and expanded use of this modality of respiratory support will require more extensive safety data and efficacy should be assessed in an interventional study comparing HFNC with other forms of respiratory support. A multicentre study comparing HFNC and low-flow nasal prong therapy has commenced in Australia and New Zealand.

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Acknowledgements The study investigators would like to thank clinical staff for completing the clinical report forms, the Royal Children's Hospital ED educators for providing ongoing high-flow nasal cannula (HFNC) training and paediatric intensive care unit outreach staff for supporting the use of HFNC outside of the intensive care unit.

Contributors EL designed the study, collected the data and wrote the manuscript. FEB submitted the ethics application and revised the manuscript. TD wrote the high-flow guideline included as an appendix and revised the manuscript.

Funding This study was supported by a National Health and Medical Research Council Centre of Research Excellence Grant for Paediatric Emergency Medicine (GNT1058560), Canberra, Australian Capital Territory, Australia and the Victorian Government's Infrastructure Support Program, Melbourne, Australia.

Competing interests None declared.

Ethics approval Human Research in Ethics Committee at the Royal Children's Hospital Melbourne (approval number: 32214 A).

Provenance and peer review Not commissioned; externally peer reviewed.

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High flow nasal prong HFNP oxygen therapy

- - Introduction & aim
 - Indications
 - Contraindications
 - Management
 - equipment
 - setup
 - patient management
 - Weaning
 - Complications

Introduction

Humidified high flow nasal prong (cannula) oxygen therapy is a method for providing oxygen and continuous positive airway pressure (CPAP) to children with respiratory distress. It is used for the same indications as the traditional method of CPAP using a nasopharyngeal tube. HFNP may reduce need for NCPAP/intubation, or provide support post extubation. At high flow of 2 litres per kg per min, using appropriate nasal prongs, a positive distending pressure of 4-8 cmH₂O is achieved. This improves functional residual capacity thereby reducing work of breathing. Because flows used are high, heated water humidification is necessary to avoid drying of respiratory secretions and for maintaining nasal cilia function.

Aim

The aim of this guideline is to describe the indications and procedure for using high flow nasal prong oxygen

Indications

HFNP are used for the same indications as the traditional method of CPAP using a nasopharyngeal tube:

- Respiratory distress from bronchiolitis, pneumonia, congestive heart failure, etc
- Respiratory support post extubation and mechanical ventilation
- Weaning therapy from mask CPAP or BIPAP
- Respiratory support to children with neuromuscular disease
- Apnoea of prematurity

High flow can be used if there is hypoxaemia (SpO₂<90%) and signs of moderate to severe respiratory distress despite standard flow oxygen.

Contraindications

- Blocked nasal passages/choanal atresia
- Trauma/surgery to nasopharynx

Management

Equipment

- Oxygen and air source
- Blender
- Flow meter
 - <7Kg use standard 0-15L/min flow meter
 - >7Kg use high flow oxygen flow meter which delivers up to 50L/min flow
- Humidifier (Fisher and Paykel® MR850)
- Circuit tubing to attach to humidifier
 - Children <12.5kg: small volume circuit tubing (RT 329)
 - Children ≥12.5kg: adult oxygen therapy circuit tubing (RT203) and 22mmF oxygen stem connector (Intersurgical 1568)
- Nasal cannula (prongs) to attach to humidifier circuit tubing (size to fit nares comfortably)
 - Newborn: OPT312 Premature or OPT314 Neonatal (maximum flow 8L/min)
 - Infants and children up to 10kg: OPT316 Infant (max flow 20L/min) or up to 12.5kg: OPT318 Paediatric cannula (max flow 25L/min)
 - Children >10kg: Adult cannula size S OPT542, size M OPT544, size L OPT546
- Water bag for humidifier
- Nasogastric tube

Set Up of equipment

- Select appropriate size nasal cannula and circuit tubing for patient size
- Connect nasal cannula to adaptor on circuit tubing, and connect circuit tubing to humidifier
- Attach air and oxygen hoses from blender to air and oxygen supply
- Connect oxygen tubing from blender to humidifier
- Use 22mmF Oxygen stem connector (Intersurgical 1568) to attach oxygen tubing to humidifier chamber with adult circuit (RT203)
- Attach water bag to humidifier and turn on to 37°C. The water bag must run freely and be placed as high as possible above the humidifier to achieve flow of water into the humidifier chamber. The system is then ready for use.
- [HFNP setup diagram](#)



Patient management

- Secure nasal cannula on patient using supplied "wiggle pads™", ensuring the prongs sit well into the nares
 - prongs should not totally occlude nares
- Start the high flow nasal cannula system at the following settings:
 - Flow rate
 - $\leq 10\text{Kg}$ 2 L per kg per minute
 - $> 10\text{Kg}$ 2 L per kg per minute for the first 10kg + 0.5L/kg/min for each kg above that (max flow 50 L/min)
 - i.e. $16\text{kg} = 20\text{L}$ (2 x first 10kg) + 3L ($0.5 \times 6\text{kg}$) = 23L/min ; $40\text{kg} = 20\text{L}$ (2 x first 10kg) + 15L ($0.5 \times 30\text{kg}$) = 35L/min
 - Start off at 6L/min and increase up to goal flow rate over a few minutes to allow patient to adjust to high flow
 - high flow meter flow should be rounded down to nearest available flow (only certain flows available)
 - FiO₂
 - Always use a blender, never use flow meter off wall delivering FiO₂ 100%
 - Start at 50-60% for bronchiolitis and respiratory distress
 - Lower FiO₂ (e.g. 21% - 25%) may be needed for cyanotic congenital heart disease with balanced circulation
 - Target range for SpO₂ of 94%-98%
 - 75-85% in cyanotic congenital heart disease with balanced circulation
 - Humidification
 - Because flows used are high, heated water humidification is necessary to avoid drying of respiratory secretions and for maintaining nasal cilia function

- Set humidifier on 37° C invasive setting (length from temperature probe to nares will result in temperature drop to comfortable level whilst maintaining optimal humidity)

Patient monitoring

- Monitor patient for response
 - Respiratory rate
 - Heart rate
 - Degree of chest in-drawing
 - SpO2
- Within 2 hours it should be possible to reduce the FiO2 and clinical stabilisation should be seen
 - The FiO2 required to maintain SpO2 in the target range (as above) should decrease to <40%
 - The heart rate and respiratory rate should reduce by 20%
 - Chest in drawing and other signs of respiratory distress should improve
- Seek medical review if any of the following occurs:
 - The patient is not stabilising as described above
 - The degree of respiratory distress worsens
 - Hypoxaemia persists despite high gas flow
 - Requirement for >50% oxygen
- Note that on high flow if high FiO2 is used, oxygen saturation may be maintained in an infant despite the development of hypercarbic respiratory failure
- If there is rapid deterioration of oxygen saturation or marked increased work of breathing, a chest x-ray should be done to exclude a pneumothorax

Patient nursing care

- All infants on high flow should have a nasogastric tube
 - Once stable on high flow, the infant should be assessed as to whether they can feed. Some infants can continue to breast feed, but most require feeding via a nasogastric tube
 - Regularly aspirate the NG 2-4 hourly for air
- Oral and nasal care must be performed 2-4 hourly
- Note nasal prongs are in correct position and no pressure areas to nares
 - Spare "wiggle pads™" available to change as required to ensure prongs secure
 - wiggle pad™ OPT010 for OPT312 Premature nasal cannula
 - wiggle pad™ OPT012 for OPT314 Neonatal, OPT316 Infant or OPT318 Paediatric nasal cannula
- Gentle suction as required to keep nares clear
- Check humidifier water level hourly

Documentation

- Document hourly on MR100 PICU observation chart:
 - Flow rate, FiO2 & humidifier temp
 - Document RR,HR, SpO2 & WOB

Weaning of high flow nasal cannula oxygen

- When the child's clinical condition is improving as indicated by:
 - Decreased work of breathing
 - Normal or improved respiratory rate
 - Return to normal cardiovascular parameters

For infants <10Kg

- The first step is to wean the FiO₂ to <40% (usually within the first 1-2 hours, as above)

40%

- Reduce flow to 5 L/min then change to standard low flow 100% oxygen (1 to 2L/min) or cease oxygen therapy if stable

For children >10Kg

- Wean FiO₂ to 40%
- Once the indication for using high flow has resolved, and the patient is stable in 40% oxygen the flow can be weaned to 1-2 L/min with FiO₂ of 100% via standard nasal prong therapy, or oxygen therapy ceased. Generally there is no need for a prolonged weaning process, better to be on high flow, standard low flow or off oxygen therapy.

Complications

- Gastric distension
- Pressure areas
- Blocked HFNP due to secretions
- Pneumothorax

Links

- [Oxygen delivery clinical practice guideline](#)

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Audit of High Flow Nasal Prong Oxygen Therapy

HFNP AUDIT

CRF 1- Treating Clinician's Report

Your name:

Supervising consultant:

Enrollment # (*office use only*):

Attach patient identification sticker here

DEMOGRAPHICS

Age: Weight:

Diagnosis:

Date / Time HFNP commenced:

RESPIRATORY THERAPY PRIOR TO HFNP

None Low flow NP oxygen

Face mask oxygen Nasopharyngeal CPAP

Mask CPAP/BiPAP

BASELINE DATA (before starting HFNP)

RR: HR: SpO2:

Respiratory Distress (mild/mod/severe):

ADDITIONAL THERAPY

Salbutamol MDI / neb Adrenaline neb

Atrovent MDI / neb

Steroid Antibiotics

Magnesium Aminophylline

INITIAL HFNP SETTINGS

FiO2: Flow rate:

2 HOURS AFTER STARTING HFNP THERAPY

FiO2:

Flow rate:

RR: HR: SpO2:

Respiratory Distress (mild/mod/severe):

TOLERABILITY

Sedation during HFNP therapy (drug/dose/freq):

Enteral feeding during HFNP therapy: Oral NG

IV fluid during HFNP therapy: Y N

OUTCOME

Weaned to low flow oxygen in ED

Transferred to ICU on HFNP

Increased support to nasopharyngeal CPAP in ED

Increased support to ETT in ED

Ceased HFNP therapy (why):

ADVERSE EVENTS

Nil

Failure of HFNP (why):

Abdominal distension

Pneumothorax

Other (specify):

CLINICIAN SATISFACTION with HFNP

Unsatisfied

Satisfied

Very satisfied