Original Article

Uses of high-flow nasal cannula on the community paediatric ward and risk factors for deterioration

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Abstract

Background: High-flow nasal cannula (HFNC) is a form of noninvasive respiratory support used for paediatric acute respiratory illnesses. Past HFNC research has focused on its use in bronchiolitis and in intensive care units, but little is reported on its use in the community hospital setting. We aimed to investigate the paediatric population using HFNC, any adverse events, and risk factors for deterioration.

Methods: A retrospective chart review was performed on patients admitted to a community paediatric ward. Inclusion criteria were patients between 1 day and 17 years of age, admitted between September 2013 and April 2016, and treated with HFNC for at least 4 hours.

Results: A total of 85 children met inclusion criteria. The average age of patients in our study was 3.41 years with 39% of patients >2 years of age. 46% of patients had an admitting diagnosis of bronchiolitis, 33% pneumonia, and 16% with asthma. Transfer rate to tertiary care centre paediatric intensive care unit was 18%. Patients transferred required greater FIO₂ (odds ratio [OR] 1.04, P=0.018, confidence interval [CI] 1.007 to 1.082), and were 3.2 times more likely to be positive for respiratory syncytial virus (RSV) (P=0.081, CI 0.868–11.739). There were no adverse events attributed to HFNC in the population.

Conclusion: HFNC is being utilized in the community hospital setting for children of varied age and types of respiratory illnesses. Children requiring higher FIO₂ are at risk of respiratory deterioration which may identify them earlier for transfer to tertiary care. Further research into the safety and efficacy of HFNC for different paediatric illnesses in the community is needed.

Keywords: Bronchiolitis; Community hospital; High-flow nasal cannula; Paediatric; RSV.

High-flow nasal cannula (HFNC) is a form of noninvasive respiratory support becoming increasingly implemented on the paediatric ward in nontertiary care centres. It provides humidity with oxygen flow at a rate higher than the patient's inspiratory flow rate, promoting washout of CO₂ in the nasopharyngeal dead space. HFNC has been found to improve patient comfort, reducing dry mouth and tachypnea while assisting in mucociliary clearance (1,2). Overall, studies have shown HFNC

to be safe in the paediatric population, and adverse events are uncommon (3,4). Research has shown that HFNC is a cost effective way to treat bronchiolitis (5), and superior to low-flow oxygen for more severe disease, so it seems advantageous for many hospitals to adopt its use (5–7). However, there is reluctance in many paediatric tertiary care centres to use HFNC outside of the ICU setting. There is a paucity of data available on its use in a community paediatric ward, and the majority of

current research is from outside of North America and has focused mainly on the treatment of bronchiolitis (7–10).

Grand River Hospital (GRH) in Kitchener, Ontario, is a secondary care hospital with 1,200 paediatric admissions per year to 13 paediatric beds equipped with central cardiorespiratory monitoring. The hospital also provides an respiratory syncytial virus (RSV) prophylaxis program. There are three tertiary care centres within 100 km of the hospital. HFNC for patients >18 years was introduced on the paediatric ward and emergency department (ED) in the fall of 2013. Prior to this, options for treatment of respiratory illness were low-flow oxygen, or invasive ventilation that ultimately required transfer to tertiary care ICU.

Our retrospective study aimed to describe the patient population receiving HFNC on our paediatric ward with respect to admitting diagnoses, age, sex and comorbidities, and the outcomes in this population including length of stay, adverse events, and mortality. In addition, we wanted to learn the characteristics of the population who medically-deteriorated and required transfer to a paediatric intensive care unit. We hypothesized that HFNC was being used on our wards for a variety of respiratory illness-types and that there were minimal adverse events. We suspected that prematurity and younger age would predict deterioration.

METHODS

We conducted an observational study in the form of a retrospective chart review. Included in our study were paediatric patients between the ages of 1 day and 17 years old admitted to the GRH paediatric ward between September 2013 and April 2016, and having received HFNC for at least 4 hours as part of their treatment regimen, which may have been initiated in the ED. Patients for which we were not able to obtain complete data were excluded.

At our centre, the Optiflow HFNC System (Fisher & Paykel Healthcare, Auckland, New Zealand) was used at the appropriate size nasal cannula for the patient and would start at a rate of 1–2 L/minute/kg and titrate flow and fraction of inspired oxygen (FIO₂) to maintain oxygen saturations >91%. At the time of our study, the hospital did not have a protocol for identifying or initiating patients on HFNC, but it was at the discretion of the attending paediatrician or emergency department physician and respiratory therapist. Patients felt to be candidates were those requiring more respiratory support than low-flow oxygen could provide but did not yet require invasive ventilation, including children in mild to moderate respiratory distress after treating their underlying disease, those with high oxygen needs, and those who may benefit from humidified air for mucociliary clearance. Patients were identified for the study through a search of patient records on the hospital's Horizon Electronic Documentation system. The patient's medical chart was

reviewed for additional demographic information. A total of 95 children were identified, but 10 of these patients were excluded as they had incomplete documentation regarding HFNC usage. Therefore, 85 patients were included in our study.

Through chart review, variables were recorded including length of stay, time between admission and initiation of HFNC, if HFNC was initiated in the emergency department vs. on the paediatric ward, and duration of HFNC therapy. Patient-related variables collected included age, sex, prematurity <36 weeks, being a twin/triplet, history of home O₂ requirements, cardiac disease, and other comorbidities. Disease-related variables included admission diagnosis, indication for starting HFNC, whether the patient received RSV prophylaxis that season and the result of a nasal pharyngeal swab (NPS) for viruses taken at admission. Interventional variables include maximum HFNC flow rate and highest FIO₂ required, and any inhaled medications or antibiotics administered during the admission. Finally, outcomes assessed included intubation at GRH, transfer to tertiary care centre ICU versus discharge from the community hospital, and adverse events associated with the use of HFNC. Treatment failure with HFNC was defined as a respiratory deterioration requiring transfer to a tertiary care centre ICU. A multivariate logistic regression analysis of selected variables was performed using SAS version 4.3 statistical software. The minimum level of statistical significance was defined as 5%, and goodness of fit was measured with C-statistic.

Ethical and institutional approvals for the study were granted by the *Tri-Hospital Research Ethics Board*.

RESULTS

Patient demographics

Patient demographic data is summarized in [Table 1](#). Our study population was 54% male and 46% female. The average age of all subjects in our study was 3.41 years. Nine of 85 subjects (11%) were born prematurely, however, only 3 of these subjects presented within 6 months of birth. All 3 subjects received adequate RSV prophylaxis in the current season, however 2 ultimately had a positive NPS for RSV on admission, while the third had an NPS positive for influenza A. Five of our 85 subjects (6%) were on home oxygen at the time of hospitalization, with an average requirement of 0.79 L/minute via nasal prongs. Six of our subjects (7%) had a history of heart disease, including atrial septal defects, post-transplant for hypoplastic left heart syndrome and tetralogy of fallot, at an average age of 2.63 years. However, the heart disease in these patients was not considered to be hemodynamically significant at the time of admission. In regards to other medical comorbidities, 15 (18%) had previous diagnoses of asthma or reactive airway disease, 15 (18%) had a pre-existing neurological disorder such as cerebral palsy, seizure disorder, and hypotonia, 7 (8%) with allergy/eczema/

Table 1. Demographics and characteristics of study population

Patient Demographic Variable:	All patients (n=85)
Age	
Average (years)	3.41
< 12 months	36 (42%)
12–24 months	16 (19%)
24 months to 17 years	33 (39%)
Sex	
Male	46 (54%)
Female	39 (46%)
History of prematurity (<37 weeks GA)	9 (11%)
<28 weeks	5 (6%)
28–32 weeks	1 (1%)
32–36 weeks	3 (4%)
Medical comorbidities	
Cardiac disease	6 (7%)
Asthma	15 (18%)
Other atopic diathesis	7 (8%)
Neurological disorder*	15 (18%)
CLD/BPD**	6 (7%)
None known	45 (53%)
Requiring intubation	5 (6%)
Requiring transfer	15 (18%)

*Neurological disorders such as Cerebral Palsy, seizure disorder, hypotonia.

**CLD/BPD = chronic lung disease/bronchopulmonary dysplasia.

atopic diathesis, 6 (7%) with chronic lung disease/bronchopulmonary dysplasia as a neonate.

Disease-related variables

Data regarding illness-related variables is summarized in Table 2. In our study, 39 patients (46%) had a primary admitting diagnosis given by the paediatrician of bronchiolitis, 28 (33%) with pneumonia, and 14 (16%) with asthma exacerbation. In particular, of patients born prematurely, 5 of 9 (56%) had diagnoses of bronchiolitis and 3 (33%) had diagnoses of pneumonia. Of patients under the age of 24 months, 35 (67%) were admitted with a diagnosis including bronchiolitis, 13 (25%) with pneumonia, and 5 (10%) with asthma. Of patients over the age of 2 years, 3 (9%) were admitted with a diagnosis of bronchiolitis, 15 (45%) with pneumonia, and 12 (36%) with asthma. Within our population of patients with a previous diagnosis of a neurological disorder, 6 of 15 (40%) of patients were admitted with diagnoses of pneumonia, and 2 of 15 (13%) with a diagnosis of asthma. Of all patients included, 28 (33%) had an NPS testing positive for RSV, 24 (28%) for rhinovirus, 22 (26%) for enterovirus, 7 (8%) testing positive for influenza, and 7 (8%) testing positive for other viruses (including adenovirus, metapneumovirus, parainfluenza virus).

Intervention variables

On average, 24 patients (28%) were started on HFNC in the emergency department and 59 (69%) had HFNC initiated after admission to the paediatric ward. Flow rates (L/minute) and FIO₂ requirements were stratified based on age, as summarized in Figure 1. Average length of time on HFNC for all study patients was 2.27 days. The longest HFNC treatment period was 9 days and the shortest period was 4 hours. When stratified based on admitting diagnosis, average length of time on HFNC for those with a diagnosis of asthma was 1.93 days, for bronchiolitis 2.15 days, and for pneumonia 2.94 days. Average time between admission and initiation of HFNC was 0.8 days (18.4 hours), and average length of stay in hospital for all patients was 6.1 days. For patients with comorbid neurological diagnoses, the average length of time on HFNC was longer at 3.16 days, and average length of hospital stay was 7.1 days. In regards to adjunctive management, of the 85 patients in our study, 54 (64%) were prescribed antibiotics during their admission and 75 (88%) received inhaled medication(s). Of note, all 39 patients with an admission diagnosis of bronchiolitis received inhaled medications during their admission.

Disposition variables

Of the 85 patients, a total of 15 (18%) ultimately required transfer to a tertiary care centre which occurred an average of 2.9 days after hospital admission. Five of these patients required intubation at GRH prior to transfer. Table 2 divides illness variables between those transferred and discharged home. The average age of patients who required transfer was 3.5 years. Eight of 15 (53%) of those transferred were < 12 months of age. Only one of these patients was born prematurely (with a gestational age of 30 weeks). In regards to pre-existing medical conditions in children transferred, three (20%) of the patients had been diagnosed previously with asthma, and three (20%) of the patients had a diagnosis of a neurological disorder. In the treatment failure cohort, nine (60%) had an admitting diagnosis of bronchiolitis in contrast to 44% of those discharged. Three patients (20%) had an admitting diagnosis of pneumonia and two (13%) with asthma. In patients who were ultimately transferred, an average of 6.16 hours elapsed between admission and the need for initiation of high-flow therapy versus 21.7 hours in the patients who remained.

Multivariate analysis (Table 3) was used to analyze the relationship between selected disease variables and risk for transfer to tertiary care. C-Statistic was 0.772 indicating good model reliability (11). Maximum FIO₂ requirements in patients who were transferred were greater than those who were discharged (odds ratio [OR] of 1.044 per unit FIO₂ increase, P=0.0182, confidence interval [CI] 1.007 to 1.082) (Figure 1). Patients requiring transfer were more likely to have an NPS swab positive for RSV (OR 3.193, P=0.0806, CI 0.868 to 11.739).

Table 2. Illness and therapy variables for all patients vs. those requiring transfer vs. discharged

	All patients (n=85)	Transfer (n=15)	Discharged (n=68)
Admission Diagnosis (Including)			
Bronchiolitis	39 (46%)	9 (60%)	30 (44%)
Pneumonia	28 (33%)	3 (20%)	23 (34%)
Asthma	14 (16%)	2 (13%)	12 (18%)
Other*	12 (14%)	1 (7%)	11 (16%)
NPS Swab Results (Including)			
RSV+	28 (33%)	8 (53%)	20 (29%)
Rhinovirus	24 (28%)	4 (27%)	19 (28%)
Enterovirus	22 (26%)	4 (27%)	18 (26%)
Influenza	7 (8%)	0	7 (10%)
Other**	7 (8%)	1 (7%)	6 (9%)
Medical Therapy Variables:			
Requiring inhaled meds:	75 (88%)	15 (100%)	58 (85%)
Requiring antibiotics	54 (64%)	8 (53%)	42 (62%)
Hrs between admission and HFNC	18.4	6.16	21.7
HFNC started in ED	24 (28%)	5 (33%)	18 (26%)
HFNC started on ward	59 (69%)	10 (67%)	48 (71%)
Average HFNC FIO2 (%)	51.4	59.3	48.9
Average duration of HFNC (days)	2.27	1.12	2.66
Average duration hospital stay (days)	6.1	2.9	5.87

ED Emergency department; HFNC High-flow nasal cannula; NPS Nasal pharyngeal swab.

*Other admission diagnoses, i.e., meconium aspiration, vaso-occlusive crisis, post-op respiratory failure.

**Other NPS results, i.e., metapneumovirus, adenovirus, parainfluenza.

Figure 1. Variables associated with likelihood of transfer to tertiary care center. Odds ratios with 95% confidence intervals.

Adverse outcomes

Over our study period two deaths occurred, both of which were patients with advanced medical directives requesting no intubation in the event of respiratory deterioration and both had admitting diagnoses of respiratory failure. No cases of pneumothorax were documented.

DISCUSSION

Our study is the first to describe the practical use of HFNC on a community paediatric ward in Canada. The research into HFNC in the paediatric population to date has focused on children <2 years of age (5,6,9,10,12), but practically we found that HFNC is being used for a larger paediatric population, as 39% of our patients were >2 years. Existing research has also focused on its use in bronchiolitis, and less is known about its efficacy in other respiratory conditions. In our study, 54% of children using HFNC had an admitting diagnosis other than bronchiolitis, including pneumonia and asthma. Although the effectiveness of HFNC has been demonstrated in younger children with bronchiolitis, evidence in the form of large paediatric randomized trials of HFNC for other respiratory diagnoses is lacking (6,7).

Although this was not a formal safety study, we found that there were no adverse events attributed to use of HFNC. This is consistent with similar research in other countries that are commonly using HFNC on a general paediatric ward (8). The majority of children in our study had a short treatment course (average 3 days) and were successfully discharged home.

Our study was also able to identify that children requiring higher FIO2 are at greater risk for deterioration while on HFNC

Table 3. Multivariate logistic regression analysis of factors associated with transfer to tertiary care centre

Variables	Discharge (n=68) Transfer (n=15)		Regression Co. SE		OR	P-value	CI
Age < 12 months	41%	53%	0.00236	0.0986	1.002	0.9809	0.826–1.216
Sex (Female)	49%	33%	−1.0777	0.7529	0.34	0.1377	0.082–1.412
No comorbidities	56%	47%	−0.7194	0.8002	0.487	0.3686	0.101–2.337
RSV+	29%	53%	1.1609	0.6643	3.193	0.0806	0.868–11.739
Max FIO2%	48.9	59.3	0.0432	0.0183	1.044*	0.0182**	1.007–1.082

CI Confidence interval; OR Odds ratio; Regression Co (Coefficient); SE Standard error.

*OR per unit increase in FIO2% (continuous variable).

**Statistically significant P-value < 0.05.

in a community hospital. RSV positive patients were three times more likely to deteriorate. This knowledge could assist the clinician in identifying high-risk patients and guide treatment decisions toward a lower threshold for early transfer to tertiary care. This would hopefully help to avoid complications during transport and thereafter. Interestingly, younger age, prematurity, medical comorbidity, or a diagnosis of bronchiolitis, were not found to be risk-factors for deterioration. Given all of the premature subjects in the study had received seasonal prophylaxis for RSV this was likely a protective factor. Our findings are consistent with a study by Betters et al. (2017) who investigated a larger cohort and found that FIO2 requirements greater than 50% was the largest factor associated with HFNC failure outside of the ICU, in addition to prior history of intubation and cardiac comorbidity (13). Our study was likely limited in identifying other significant variables associated with patient deterioration by the size and heterogeneity in the sample at our community hospital, and a multicentre study may be helpful in finding other relevant risk factors in such a broad group of paediatric patients.

We must recognize that the population of patients using HFNC are at high-risk of deteriorating and require a greater degree of medical support, as 18% of our patient population eventually required transport to tertiary care and five children required intubation. One third of the patients on HFNC presented to ED with acute distress and were initiated on treatment before being transferred to the ward. Utilizing HFNC on the community ward, compared to paediatric ICU, requires the ward to be capable of intensive monitoring, including dedicated nursing and RT support, which may be more than some community hospitals are able to provide. In addition, transport teams need to be equipped to safely treat children on HFNC during transport to avoid complications such as unnecessary intubations. The development of evidence-based protocols for the initiation of HFNC on the community paediatric ward in Canada are needed, and will ideally result in more patients being treated successfully in their own community.

CONCLUSION

HFNC is currently being used on the community hospital paediatric ward for a variety of respiratory illnesses in children <18 years

with minimal adverse outcomes. Children requiring higher oxygen needs and possibly also with RSV are more likely to deteriorate on HFNC and require transfer to tertiary care. Early identification of children at risk may improve care. Further research into HFNC efficacy in respiratory illnesses other than bronchiolitis, in older children, and those with complex medical needs is essential.

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