

Is implementation of a hospital pathway for high-flow nasal cannula initiation and weaning associated with reduced high-flow duration in bronchiolitis?

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Abstract

Background: High-flow nasal cannula (HFNC) therapy is widely used for children with bronchiolitis, but its optimal role remains uncertain. Our institution created and later revised a clinical pathway guiding HFNC initiation and weaning.

Methods: A retrospective review of 1690 bronchiolitis encounters was conducted. Trends in the duration of HFNC and hours spent weaning HFNC as proportions of the monthly hospital length of stay (LOS) for bronchiolitis, hospital LOS, and escalation of care were compared using interrupted time series (ITS) models across three study periods: Baseline (HFNC managed at provider discretion), Intervention 1 (pathway with initiation at 0.5 L/kg/min and escalation up to 2 L/kg/min), and Intervention 2 (revised pathway, initiation at the maximum rate of 2 L/kg/min). Both pathway iterations provided titration and weaning guidance. Maximum respiratory scores were used to adjust for case severity.

Results: After adjustment for severity and time, both HFNC duration and HFNC weaning time (as a proportion of monthly LOS) decreased at the start of Intervention 1, but subsequently increased. During Intervention 2, both these measures trended downward, returning to baseline. Total LOS did not change in the baseline or intervention periods. Escalation of care did not differ from baseline to the end of Intervention 2.

Conclusion: Initiating HFNC at higher flow rates with weaning guidance for children hospitalized with bronchiolitis was associated with a reduction in HFNC duration without differences in LOS or escalation of care. These findings suggest that standardization through clinical pathways can limit HFNC duration in bronchiolitis.

KEYWORDS

bronchiolitis, evidence-based medicine & outcomes, heated high-flow nasal cannula (HFNC), oxygenation and therapy, respiratory syncytial virus (RSV)

These data were presented at the Pediatric Hospital Medicine Meeting (virtual) in August 2021. A related but separate analysis of the data was previously presented locally at the Child Health Research Institute Pediatric Research Forum (virtual) in May 2020.

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1 | INTRODUCTION

Acute viral bronchiolitis is a major cause of hospitalization for children under 2 years of age.¹⁻⁴ Current evidence promotes predominantly supportive care.³ Heated, humidified high-flow nasal cannula (HFNC) therapy has emerged as a widely used therapy for bronchiolitis over the past decade.^{1,5} However, the optimal role of HFNC in the management of children hospitalized with bronchiolitis remains uncertain.

The utility of HFNC in bronchiolitis is likely limited, as some studies propose potential improvement in clinical outcomes like escalation of care,⁶⁻⁹ but a lack of significant changes in measures such as length of stay (LOS) or duration of therapy.⁹⁻¹⁴ Evidence suggests that HFNC may be safely and most effectively used as rescue therapy for hypoxemic patients with bronchiolitis after initial standard oxygen therapy (SOT) fails, occupying a space between SOT and more invasive support.^{10,12,13,15,16}

While the incidence of hospitalizations for bronchiolitis has decreased in the past decade in the United States, hospital direct cost has increased, along with the proportion of complex chronic patients.¹ In a North American survey, three fourths of sites using HFNC on pediatric wards had locally developed protocols, with most maximum flow rates being lower than 2 L/kg/min (most US sites used a maximum of 6-8 L/min on the wards). Only 68% of the protocols addressed initiation and ongoing assessment, while 57% addressed weaning.¹⁷ Of the studies included in a systematic review of HFNC in bronchiolitis, only one trial included a defined oxygen weaning protocol.¹² In a US survey of HFNC practices across institutions, only 37% of institutions with HFNC guidelines used a protocol to determine initial flow rates; weaning practices were highly variable.¹⁸

National experts recommend greater standardization in HFNC use, including providing a protocol for HFNC initiation,¹⁹ with practice standardization projects being developed to reduce excessive use.^{20,21} In a PICU quality improvement/pre-post intervention study, standardizing HFNC use with a protocol using higher initial flow rates was associated with faster weaning and decreased HFNC failure.²² Likewise, an RT-driven PICU protocol for HFNC initiation and weaning was associated with decreased LOS and therapy duration.²³ On the wards, a multi-center study found a weight-based protocol was associated with decreased ICU utilization, noninvasive ventilation (NIV) use, and cost.²⁴ Existing literature underscores the importance of improving resource utilization by optimally targeting HFNC use without prolonging time on respiratory support or LOS.

The purpose of our study is to analyze the association of implementing and modifying a clinical pathway standardizing HFNC use on clinical outcomes and measures of HFNC utilization.

2 | MATERIALS AND METHODS

2.1 | Study setting and design

This study occurred at a 145-bed free-standing children's hospital in the Midwest, where care is provided for an average of 600 children

with bronchiolitis annually. Retrospective data were collected for all patients admitted to the inpatient wards with a diagnosis of acute viral bronchiolitis. Outcomes were compared using interrupted time series (ITS) models across three time periods: Baseline (no formal pathway, 5/1/2015-4/30/2017), Intervention 1 (first pathway, 5/1/2017-2/28/2018), and Intervention 2 (revised pathway, 3/1/2018-12/31/2019).

2.2 | Study participants

We retrospectively reviewed the medical records of all children admitted with a diagnosis of acute viral bronchiolitis during the study period. Eligible patients were identified through administrative billing codes, similar to prior studies.²⁵ Patients with a diagnosis code for bronchiolitis (primary diagnosis or non-primary) met the criteria for review. Encounters were excluded if the patient had a diagnosis indicating the presence of a complex medical condition (such as hemodynamically significant cardiac disease, chronic kidney disease, and tracheostomy status), invasive bacterial infections (defined as bacteremia or meningitis), or if the bronchiolitis encounter had a co-morbid acute asthma exacerbation that would have excluded the patient from the HFNC pathway (Figure 1). Encounters were also excluded if the patient underwent a surgical procedure, was admitted directly to the PICU, or had a total LOS > 14 days, as review of these hospitalizations suggested that HFNC use was not primarily due to bronchiolitis (Figure 1). Apart from these exclusions, patients with chronic lung disease or a history of prematurity were included to realistically represent populations commonly hospitalized with bronchiolitis. Likewise, patients with any diagnosis code for bacterial pneumonia were not excluded to capture the full range of bronchiolitis presentations, which can include a concomitant diagnosis of bacterial pneumonia. Including these patients also allowed us to include bronchiolitis patients with a broader range of severity.

Qualifying Encounters

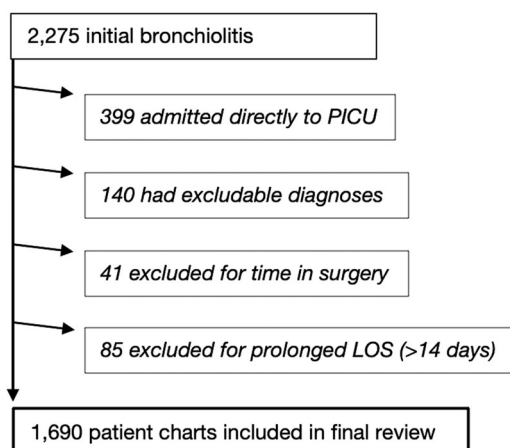


FIGURE 1 Study inclusion flow diagram

2.3 | Intervention development and implementation

Before May 2017, HFNC was used for several years in the wards and emergency department (ED) at provider discretion without a pathway or strictly defined flow limits. In May 2017, our institution implemented a pathway for HFNC initiation, titration, and weaning on the wards, including guidance regarding maximum flow rates. The team creating, and later modifying, the pathway consisted of pediatric hospitalists, a pediatric pulmonologist, a pediatric intensivist, nursing leadership, respiratory therapy leadership, and support from the hospital performance improvement department. The team utilized available literature to guide pathway development.

The pathway was initiated for children under 2 years of age but older than 40 weeks post-conceptual age with either respiratory distress, hypoxemia (as defined by oxygen requirement greater than 1 L for those age 30–90 days, 1.5 L for age 91 days to 6 months, and 2 L for 6 months to 2 years), or a moderate or higher respiratory score. Complex patients with known cardiac disease, anatomic airway defects, neuromuscular disease, or immunodeficiency were excluded from the pathway. HFNC was delivered by Fisher and Paykel Optiflow Junior, which has an upper limit of 15 L/min.

The first HFNC pathway recommended an initial rate of 0.5 L/kg/min with escalation up to 2 L/kg/min, and a maximum rate of 15 L/min. For patients continuing to clinically worsen, a multidisciplinary huddle at 60 min post-HFNC escalation was encouraged to assess the need for PICU transfer. The pathway included guidance, without being prescriptive, for weaning or stopping HFNC with the goal of reducing hospital LOS. The FiO₂ could be weaned by RN/RT with a goal of maintaining saturations at or above 90%. Respiratory therapy was instructed to call the provider and request decreasing flow rates by at least 1 L every 2 h for patients who were clinically improving and/or requiring less than 30% FiO₂. Such weaning could take place throughout the day and overnight. When the flow rate was stable at 2 L for 2 h, HFNC could be discontinued and low-flow nasal cannula could be used to maintain saturations at or above 90% while awake and 88% when asleep (Figure 2). Weaning by a trial directly off HFNC to room air (RA) (from any flow rate) was also permitted.

2.4 | Modification to the intervention

In February 2018, the pathway was revised to address concerns regarding unplanned, rapid transfers from the inpatient wards to the PICU for patients admitted from the ED on HFNC. The revised pathway (Figure 2) initiated HFNC at 2 L/kg/min with a maximum flow rate of 15 L/min and had a reassessment at 2 h to determine patient disposition from the ED or (for direct admissions) patients with HFNC initiated on the wards. The revised pathway went live on March 1, 2018.

2.5 | Study outcomes and covariates

Duration of HFNC use was defined as the time from the first documentation of use of HFNC until the first documented use of low-flow nasal cannula or RA. Since patients may have used the device in more than one separate instance during their stay, HFNC duration was further defined as the first time documenting HFNC as the O₂ device until the final transition of HFNC to either nasal cannula or RA during the hospital stay. HFNC weaning duration was defined as the time from maximum documented flow rate until the final transition of HFNC to either nasal cannula or RA during the hospital stay.

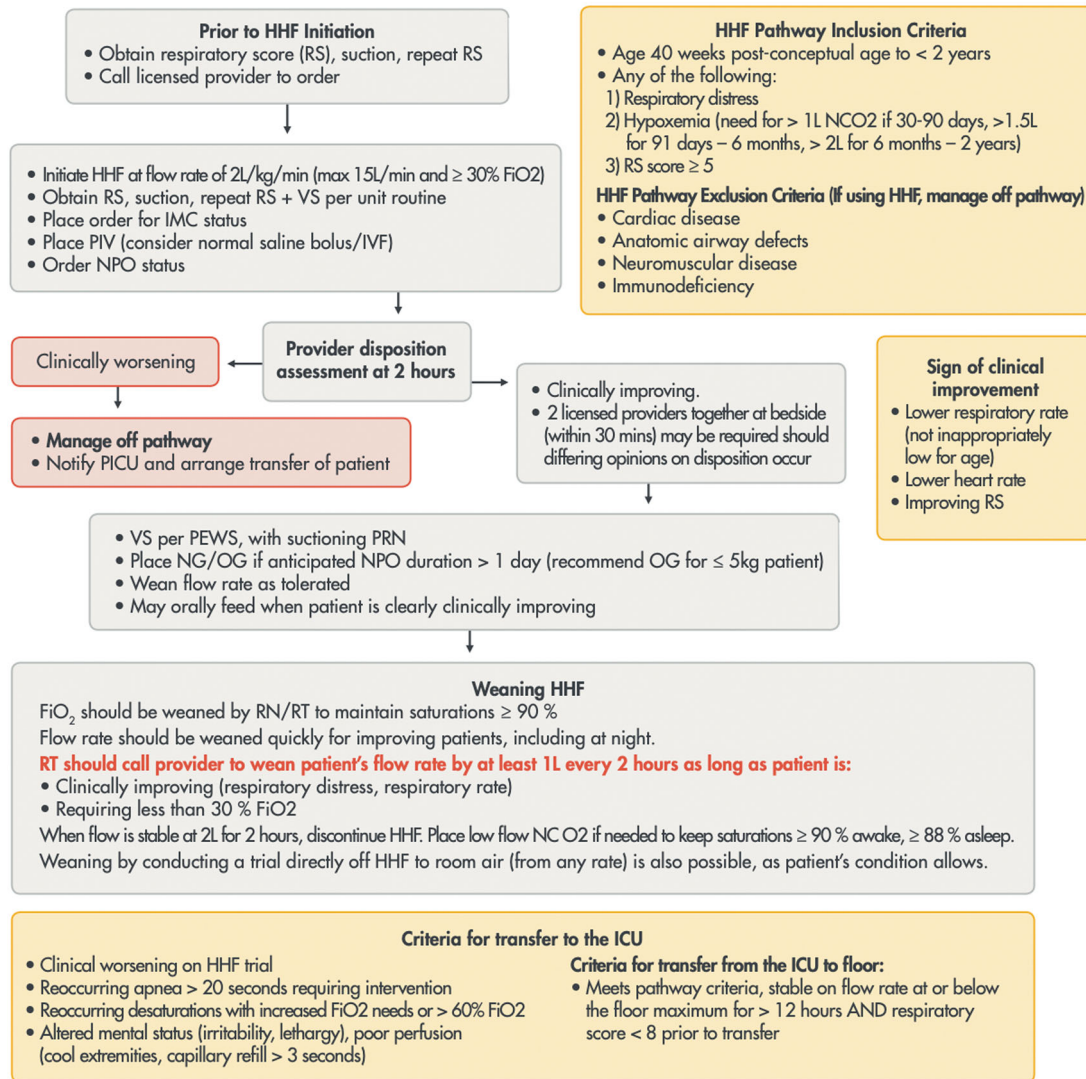
The primary outcome was the proportion of LOS on HFNC, defined as the duration of HFNC use in hours compared to the total monthly patient hours for hospitalized bronchiolitis patients. We used this measure to more accurately evaluate the amount of HFNC used by providers normalized by the total monthly hours of children hospitalized for bronchiolitis. This was done to account for seasonal variation in bronchiolitis and differences in duration due to differences in LOS. A secondary outcome was HFNC weaning duration as the proportion of total monthly hours of children hospitalized for bronchiolitis. Other secondary outcomes included hospital LOS (defined as time from admission to discharge in hours), escalation of care (defined as transfer to the PICU, intubation, or initiation of noninvasive mechanical ventilation), and maximum flow rate in L/kg/min.

We used the maximum recorded respiratory score during the hospital encounter as a covariate for illness severity. The institution's respiratory score changed in March 2017 from the Clinical Respiratory Score to the Respiratory Score (Supporting Information). Both systems stratified patients into mild, moderate, or severe categories. Criteria for PICU transfer did not change across baseline and intervention periods.

2.6 | Statistical methods

Categorical patient demographics (sex, race, and insurance) were compared across study periods using chi-squared tests. Continuous normally distributed patient demographics (age and weight) and maximum respiratory score category (mild, moderate, and severe) were compared across study periods using one-way ANOVA and Kruskal–Wallis rank sum tests, respectively. Unadjusted total HFNC duration, HFNC weaning time, and LOS were compared by study period using Kruskal–Wallis rank sum tests. Unadjusted rates of escalation of care were compared similarly using chi-squared tests. To adjust for the possibility of differing case severity mix between study periods and existing time trends in practice, monthly ITS models with interruptions at each intervention were run controlling for maximum respiratory score for total HFNC as a proportion of total LOS, HFNC weaning duration as a proportion of total LOS stay, total LOS, and escalation of care. All analyses were conducted using R 3.6.1. (R Foundation for Statistical Computing).

HEATED HIGH FLOW (HHF) PATHWAY



 Regular Information  Important Information  Escalating Care

Disclaimer: Pathways are intended as a guide for practitioners and do not indicate an exclusive course of treatment nor serve as a standard of medical care. These pathways should be adapted by medical providers, when indicated, based on their professional judgement and taking into account individual patient and family circumstances. UPDATED 8/24/18

www.ChildrensOmaha.org/Pathways-Protocols

FIGURE 2 Heated high flow pathway

2.7 | Ethics approval

The study was approved by the Institutional Review Board (IRB) at our institution. Informed consent was not required per the IRB for this retrospective review of medical records.

3 | RESULTS

Between May 1, 2015 and December 31, 2019, there were 2275 admissions to the hospital with a diagnosis of acute viral bronchiolitis; 1690 encounters met inclusion/exclusion criteria (Figure 1).

The mean age was 8 months; 106 (6%) spent time in the ICU, 84 (5%) received noninvasive ventilation, and 12 (1%) were intubated (Table 1). Patient demographics did not differ significantly across study periods (Table 1). Maximum respiratory score significantly differed between periods, with patients seen in Interventions 1 and 2

more likely to have moderate-severe maximum respiratory scores than in the baseline period (Table 1).

In the unadjusted analysis, median total HFNC duration was 45 h [IQR: 23, 69] in the baseline period, 41 h [IQR: 27, 65] in Intervention 1, and 38 [IQR: 13, 48] in Intervention 2 (Table 1). Total LOS did not

TABLE 1 Demographics, clinical presentation, and unadjusted outcomes by study period

	Baseline (5/1/ 2015–4/30/2017)	Intervention 1 (5/1/ 17–2/28/18)	Intervention 2 (3/1/ 18–12/31/19)	p Value (baseline to Int. 1; baseline to Int. 2)
Qualifying encounters	680	309	700	
Age, months (mean (SD))	8.14 (5.73)	7.75 (5.95)	7.80 (5.97)	0.35; 0.29
Male sex (%)	407 (60%)	199 (64%)	415 (59%)	0.20; 0.87
Weight, kg (mean (SD))	7.62 (2.53)	7.56 (2.63)	7.74 (2.64)	0.72; 0.82
Race/ethnicity (%)				
African American	64 (9%)	27 (9%)	56 (8%)	
Hispanic	136 (20%)	46 (15%)	123 (18%)	
White	409 (60%)	201 (65%)	431 (62%)	
Other	71 (10%)	35 (11%)	90 (13%)	
Public insurance (%)	353 (52%)	157 (51%)	336 (48%)	0.80; 0.16
Max respiratory score (%)				
Mild	438 (64%)	187 (61%)	336 (48%)	
Moderate	149 (22%)	93 (30%)	241 (34%)	
Severe	35 (7%)	11 (4%)	52 (7%)	
Missing	58 (9%)	18 (6%)	71 (10%)	
HFNC order (%)**	218 (32%)	157 (51%)	268 (38%)	<0.001; 0.018
Max flow rate, L/kg/min (median [IQR])**	0.85 [0.64, 1.26]	1.12 [0.81, 1.79]	1.63 [1.22, 1.91]	<0.001; <0.001
Duration of HFNC, h (median [IQR])**	45.3 [23.1, 68.7]	40.6 [27.5, 64.5]	38.0 [13.1, 47.8]	0.37; <0.001
Weaning (max flow to nasal cannula/ room air), h (median [IQR])	33.4 [12.6, 53.7]	33.3 [14.3, 53.9]	32.8 [15.4, 40.9]	0.67; 0.67
Total LOS, h (median [IQR])	56.1 [25.4, 93.0]	60.5 [35.7, 92.6]	48.7 [24.7, 88.8]	0.23; 0.26
Escalation of care (%)				
ICU (%)	42 (6%)	26 (8%)	41 (6%)	0.25; 0.90
ICU LOS, h (median [IQR])	54 [32.5, 92.2]	68.3 [34.3, 98.5]	71.9 [30.1, 98.5]	0.57; 0.62
Noninvasive ventilation (%)	32 (5%)	22 (7%)	30 (4%)	0.16; 0.81
Time on NIV, h (median [IQR])	72.3 [45.3, 101.0]	51.1 [41.7, 74.4]	51.2 [31.4, 70.3]	0.20; 0.11
Intubation (%)	5 (1%)	2 (1%)	5 (1%)	1.00; 1.00
Time intubated, h (median [IQR])	91.7 [4.2, 96.6]	163.7 [151.0, 176.4]	24.4 [8.0, 70.8]	0.12; 0.60
Albuterol order (%)**	116 (17%)	36 (12%)	68 (10%)	0.04; <0.001
Antibiotic order (%)*	98 (14%)	32 (10%)	69 (10%)	0.10; 0.012
Steroid order (%)	114 (17%)	50 (16%)	94 (13%)	0.89; 0.10
Chest x-ray order (%)*	199 (29%)	120 (39%)	253 (36%)	0.004; 0.008

* $p < 0.05$.

** $p < 0.001$.

differ across study periods. A significantly higher proportion of patients utilized HFNC during Intervention 1 (51%) and Intervention 2 (38%) than the baseline period (32%). During the baseline period, median maximum HFNC flow rates were 0.85 L/kg/min [IQR: 0.64, 1.26]. Maximum flow rates increased significantly during Interventions 1 and 2, with median flow rates of 1.12 L/kg/min [IQR: 0.81, 1.79] and 1.63 L/kg/min [IQR: 1.22, 1.91], respectively (Table 1).

After adjustment for severity and time trends, the monthly trends over time for both proportion of LOS on HFNC and the proportion of time spent weaning HFNC significantly decreased at the start of Intervention 1 (May 2017) but trended up at the end of this period (February 2018; Figure 3). Monthly trends in these measures began at a higher point than the baseline period during Intervention 2, but subsequently demonstrated a downward trend that was sustained throughout the following two respiratory seasons. Both these measures were trending downward at the end of Intervention 2 (December 2019). The proportion of LOS on HFNC and the proportion of time spent weaning HFNC at the end of the overall study period did not differ significantly from those at

the start of the baseline period. Adjusted LOS did not differ significantly across baseline and intervention periods (Figure 4). A small but significant downward trend in escalation of care was observed at the start of Intervention 1, but rates were similar to the baseline period at the end of the overall study period (Figure 4). Immediate changes at the time of interventions are demonstrated in Figure 5.

4 | DISCUSSION

Implementing an HFNC pathway at our institution was associated with a significant initial decrease in the duration of HFNC use, but use quickly trended upwards again. After the pathway was modified to initiate HFNC at maximum flow rates (2 L/kg/min), we observed a significant downward monthly trend in HFNC duration that was sustained through two respiratory seasons. Our results suggest that higher initial flow rates, when paired with a pathway guiding initiation and promoting weaning, may reduce excessive time on HFNC.

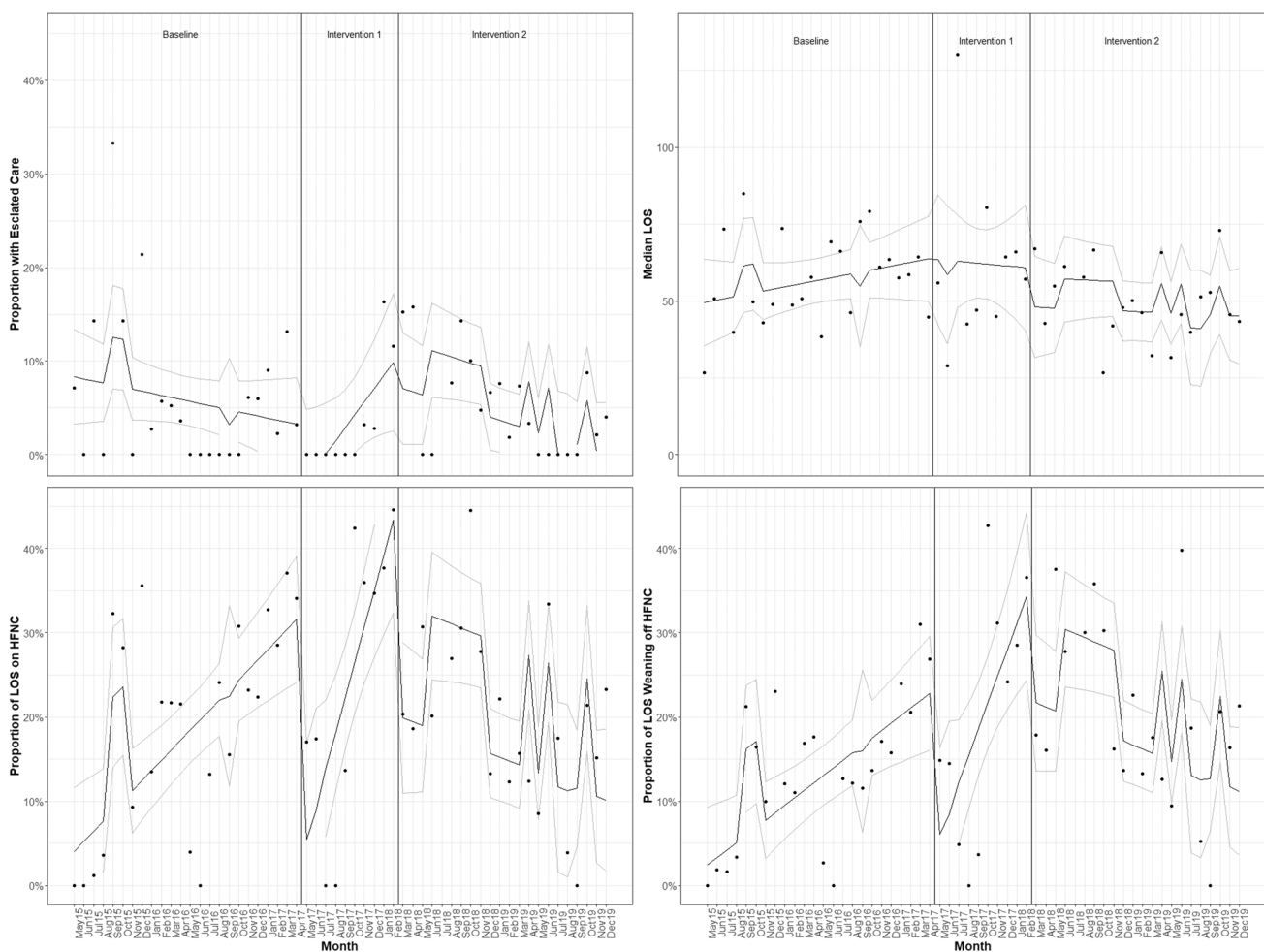


FIGURE 3 Proportion of bronchiolitis patients receiving escalated care (upper right), median length of stay in hours (upper left), proportion of patient hours spent on HFNC (bottom right), and proportion of patient hours spent weaning off HFNC (bottom left). Actual monthly values (points). Predicted monthly value from the ITS model adjusting for max respiratory score (center-line) with interruptions at each intervention. 95% confidence interval for ITS prediction (faded top and bottom lines).

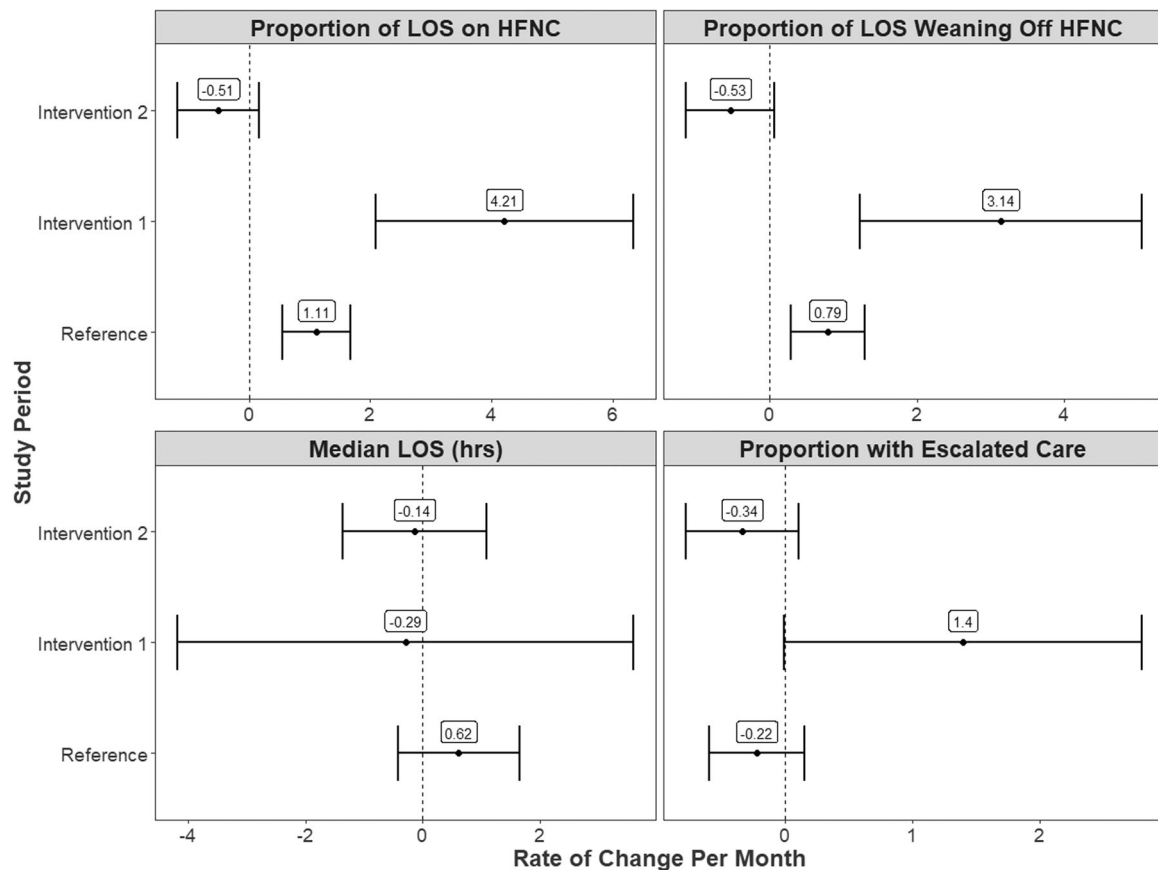


FIGURE 4 Slopes with 95% confidence interval for each time period as produced by monthly ITS model adjusting for maximum respiratory score. ITS, interrupted time series.

Our data on HFNC initiation rates from the baseline period, which began before the widespread adoption of HFNC on the wards, demonstrate a steady increase. This finding aligns with those of prior studies that have observed substantial increases in HFNC use in bronchiolitis over the past several years without meaningful clinical benefits.²⁶ This national trend may, in part, explain our observation that monthly trends in the proportions of LOS on HFNC and time spent weaning initially decreased with Intervention 1, but had climbed again by the beginning of the next respiratory season. Implementing higher initial flow rates in the revised pathway (Intervention 2) may have aided in curbing this upward trend, perhaps by discouraging HFNC initiation in patients with less severe disease.

Our revised pathway used the maximum flow rate of 2 L/kg/min as initial therapy (Intervention 2). This change was part of an effort to reduce rapid transfers from the inpatient wards to the PICU, by assisting clinicians in deciding early if the therapy was effective. As median maximum flow rates increased during Intervention 2, monthly trends in proportion of LOS on HFNC and proportion of time spent weaning decreased significantly and returned to the baseline level of use (Figures 3 and 4). This finding is particularly important given the growing national emphasis on reducing unnecessary HFNC use in bronchiolitis by appropriate initiation and weaning.¹⁹ Our study

informs de-implementation efforts by showing that standardizing HFNC initiation at higher doses was not associated with an increase in overall HFNC duration when paired with a pathway promoting weaning. This finding is in contrast to several studies cautioning providers about the questionable impact of higher flow rates, suggesting prolonged weaning.^{27,28} Higher initial maximum flow rates fit with observational and physiological studies that suggest HFNC flow rates approximating 2 L/kg/min may be necessary to unload respiratory muscles, improve work of breathing, or generate positive airway pressure in children with bronchiolitis^{29–34} and several studies of protocols with higher flow rates have demonstrated some favorable outcomes.^{22,24}

Our findings also support practice standardization and weaning guidance for mitigating prolonged HFNC duration. This aligns with a quality initiative using an RT-driven protocol for bronchiolitis patients to decrease the length of HFNC therapy and LOS.²⁰ Another QI project took a different approach and implemented once or twice daily standardized trials directly off HFNC, demonstrating decreased LOS and reduced hours of subtherapeutic flow rates.²¹ The weaning guidance within our HFNC pathway provided both RT notification to wean improving patients as well as the opportunity for providers to trial a patient directly from HFNC to room air. While this weaning guidance remained identical in Interventions 1 and 2, it is possible

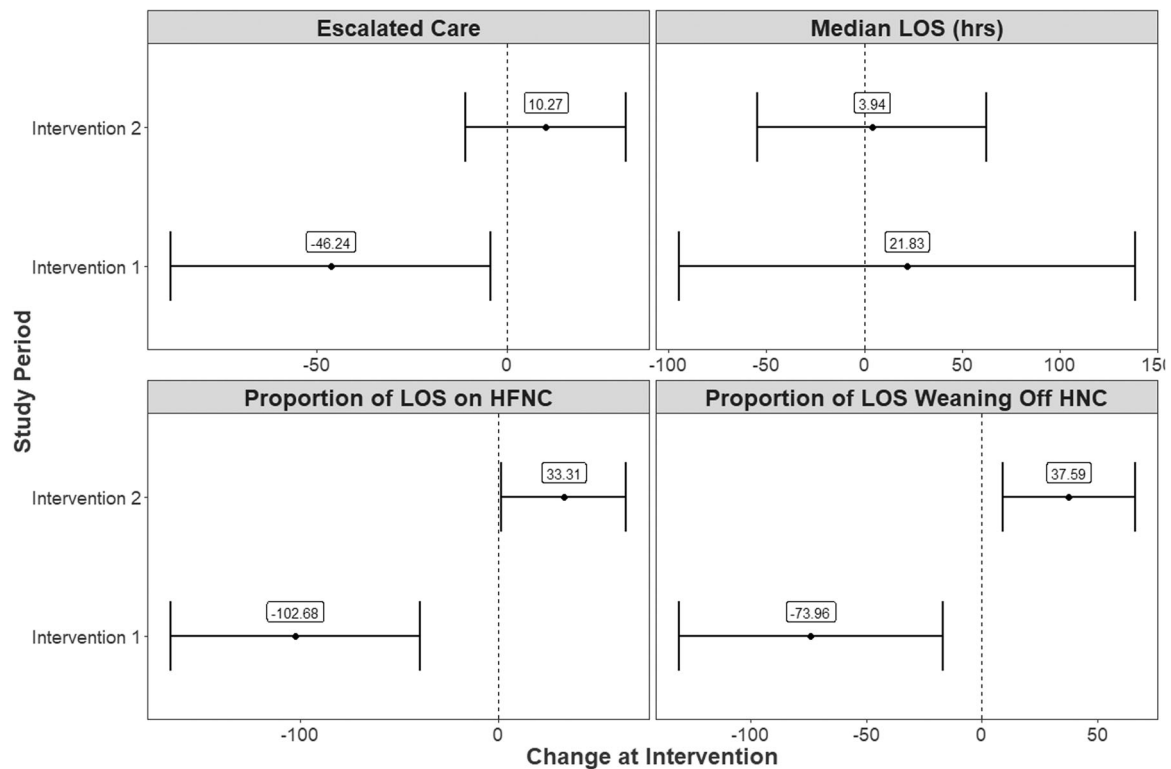


FIGURE 5 Change in intercept with 95% confidence interval for each time period as produced by monthly ITS model adjusting for maximum respiratory score. ITS, interrupted time series.

that weaning guidance was a key factor in driving the outcomes that we saw as providers gained experience with the pathway. Significant heterogeneity in protocols across institutions makes it challenging to generalize about pathway utility¹⁸ and some studies have not shown convincing benefits for HFNC pathway implementation.^{35,36} These findings suggest that the impact of a hospital pathway largely depends on the specific guidance it provides as well as its accessibility and acceptance by staff.

Our study has several limitations. This was a single-center, retrospective study in a free-standing children's hospital and may not be generalizable to other contexts. The entire study was conducted after publication of the 2014 AAP Clinical Practice Guideline for bronchiolitis and before the COVID-19 pandemic in the United States. Our analysis did not include children with time in surgery or excludable diagnoses that required off-pathway management (Figure 2), so results may not be applicable to all bronchiolitis inpatients. However, we specifically included patients with chronic lung disease, prematurity, and concomitant diagnosis codes for bacterial pneumonia, to capture a significant proportion of patients admitted with bronchiolitis. We used the electronic-health record to directly pull data on the duration of HFNC. While this method could be helpful in informing future studies evaluating similar outcomes, a resulting limitation is that our data is constrained by the accuracy with which RN/RTs documented respiratory devices and flow rates. In addition, although our goal after pathway revision was to initiate

HFNC at 2 L/kg/min, this was impossible in children over 7.5 kg due to maximum flow rates of 15 L/min on the delivery system.

The respiratory score used (Supporting Information) changed partway through the study in March 2017. While both systems stratified patients into mild, moderate, and severe categories, these scores are an imperfect measure of bronchiolitis severity and limit our ability to account for differences in case mix. Despite a shift toward more moderate or severe maximum respiratory scores during the study period, we cannot exclude the possibility that more patients with mild disease were classified as moderate or severe in the second scoring system, which would confound results.

Evidence has suggested that resource utilization in bronchiolitis varies with seasonality,³⁷ with times of lower bronchiolitis census seeing higher levels of several unnecessary interventions, which may affect our ability to compare our study periods. We attempted to adjust for these differences by using an ITS model that would allow us to compare month-to-month changes. By the time of Intervention 2, providers had been working with HFNC for several years and increasing provider experience in the latter portion of the study period may confound the findings related to downtrending duration of HFNC use. Similarly, attitudes toward HFNC in bronchiolitis may have shifted throughout the years of the study. Thus, it would be inappropriate to claim that the pathway was singularly responsible for the change in behavior surrounding HFNC observed at our institution.

The formal order set for our pathway was of low utility to providers (since HFNC is a single order) and thus infrequently used, which limits our ability to assess pathway adherence. However, significantly increasing flow rates during the intervention periods, along with anecdotal evidence from providers, are a process metric that suggests that the pathway was being implemented without formal order set use. There were many months with no patients requiring care escalation, which limits the power of our analysis of this outcome. While we did not analyze readmission, readmissions are generally rare in bronchiolitis literature and often left unanalyzed, so it is unlikely that missing these data meaningfully impacted our interpretation of results.²⁵ Likewise, secular trends in LOS for bronchiolitis have only marginally decreased over the previous decade and therefore may be a less significant confounder to consider.⁴

In conclusion, our study supports the use of a hospital pathway to guide HFNC initiation and weaning on the inpatient wards for patients with bronchiolitis. Notably, the use of higher initial flow rates (2 L/kg/min) was not associated with longer hospital stays, but with trends toward decreasing time spent on HFNC. Additional efforts to reduce unnecessary care should identify effective strategies to promote standardization of evidence-based practices for children with bronchiolitis.

AUTHOR CONTRIBUTIONS

Laura Tarantino: Data curation (equal); writing—original draft (equal). **Nathaniel Goodrich:** Conceptualization (equal); formal analysis (equal); investigation (equal); writing—review and editing (equal). **Ellen Kerns:** Data curation (equal); formal analysis (lead); investigation (equal); methodology (lead); writing—review and editing (equal). **Russell McCulloh:** Conceptualization (lead); formal analysis (equal); investigation (equal); writing—review and editing (equal). **Jason Burrows:** Conceptualization (equal); formal analysis (equal); writing—original draft (equal); writing—review and editing (equal).

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

- Fujiogi M, Goto T, Yasunaga H, et al. Trends in bronchiolitis hospitalizations in the United States: 2000–2016. *Pediatrics*. 2019;144(6):e20192614. doi:10.1542/peds.2019.2614
- Meissner HC. Viral bronchiolitis in children. *N Engl J Med*. 2016;374(18):1793–1794.
- Ralston SL, Lieberthal AS, Meissner HC, et al. Clinical practice guideline: the diagnosis, management, and prevention of bronchiolitis. *Pediatrics*. 2014;134(5):E1474–E1502.
- Hasegawa K, Tsugawa Y, Brown DF, Mansbach JM, Camargo CA Jr. Trends in bronchiolitis hospitalizations in the United States, 2000–2009. *Pediatrics*. 2013;132(1):28–36.
- Panciatici M, Fabre C, Tardieu S, et al. Use of high-flow nasal cannula in infants with viral bronchiolitis outside pediatric intensive care units. *Eur J Pediatr*. 2019;178(10):1479–1484.
- Milani GP, Plebani AM, Arturi E, et al. Using a high-flow nasal cannula provided superior results to low-flow oxygen delivery in moderate to severe bronchiolitis. *Acta Paediatr*. 2016;105(8):e368–e372.
- Goh CT, Kirby LJ, Schell DN, Egan JR. Humidified high-flow nasal cannula oxygen in bronchiolitis reduces need for invasive ventilation but not intensive care admission. *J Paediatr Child Health*. 2017;53(9):897–902.
- Franklin D, Fraser JF, Schibler A. Respiratory support for infants with bronchiolitis, a narrative review of the literature. *Paediatr Respir Rev*. 2018;30:16–24.
- Franklin D, Babl FE, Schlapbach LJ, et al. A randomized trial of high-flow oxygen therapy in infants with bronchiolitis. *N Engl J Med*. 2018;378(12):1121–1131.
- Lin J, Zhang Y, Xiong L, Liu S, Gong C, Dai J. High-flow nasal cannula therapy for children with bronchiolitis: a systematic review and meta-analysis. *Arch Dis Child*. 2019;104(6):564–576.
- Kepreotes E, Whitehead B, Attia J, et al. High-flow warm humidified oxygen versus standard low-flow nasal cannula oxygen for moderate bronchiolitis (HFWHO RCT): an open, phase 4, randomised controlled trial. *Lancet*. 2017;389(10072):930–939.
- Moreel L, Proesmans M. High flow nasal cannula as respiratory support in treating infant bronchiolitis: a systematic review. *Eur J Pediatr*. 2020;179(5):711–718.
- O'Brien S, Craig S, Babl FE, Borland ML, Oakley E, Dalziel SR. 'Rational use of high-flow therapy in infants with bronchiolitis. what do the latest trials tell us?' A paediatric research in emergency departments international collaborative perspective. *J Paediatr Child Health*. 2019;55(7):746–752.
- Lo H, Moore R, Rodkey T, et al. High-flow nasal cannula utilization rates and outcomes in bronchiolitis patients. *Pediatrics*. 2019;144:482.
- Habra B, Janahi IA, Dauleh H, Chandra P, Vetan A. A comparison between high-flow nasal cannula and noninvasive ventilation in the management of infants and young children with acute bronchiolitis in the PICU. *Pediatr Pulmonol*. 2020;55(2):455–461.
- Fainardi V, Abelli L, Muscara M, Pisi G, Principi N, Esposito S. Update on the role of high-flow nasal cannula in infants with bronchiolitis. *Children*. 2021;8(2):66. doi:10.3390/children8020066
- Kalburgi S, Halley T. High-flow nasal cannula use outside of the ICU setting. *Pediatrics*. 2020;146(5):e20194083. doi:10.1542/peds.2019.4083
- Cheng AY, Simon HK, Miller J, Wetzell M, Zmitrovich A, Hebbbar KB. Survey of current institutional practices in the use of high-flow nasal cannula for pediatric patients. *Pediatr Emerg Care*. 2022;38(1):e151–e156.
- Ralston SL. High-flow nasal cannula therapy for pediatric patients with bronchiolitis: time to put the horse back in the barn. *JAMA Pediatr*. 2020;174(7):635–636.

20. Charvat C, Jain S, Orenstein EW, Miller L, Edmond M, Sanders R. Quality initiative to reduce high-flow nasal cannula duration and length of stay in bronchiolitis. *Hosp Pediatr*. 2021;11:309-318.
21. Noelck M, Foster A, Kelly S, et al. SCRATCH trial: an initiative to reduce excess use of high-flow nasal cannula. *Hosp Pediatr*. 2021;11(4):319-326.
22. Wisner RK, Smith AC, Khallouq BB, Chen JG. A pediatric high-flow nasal cannula protocol standardizes initial flow and expedites weaning. *Pediatr Pulmonol*. 2021;56(5):1189-1197.
23. Peterson RJ, Hassumani DO, Hole AJ, Slaven JE, Tori AJ, Abu-Sultaneh S. Implementation of a high-flow nasal cannula management protocol in the pediatric ICU. *Respir Care*. 2021;66(4):591-599.
24. Willer RJ, Johnson MD, Cipriano FA, et al. Implementation of a weight-based high-flow nasal cannula protocol for children with bronchiolitis. *Hosp Pediatr*. 2021;11(8):891-895.
25. Mussman GM, Lossius M, Wasif F, et al. Multisite emergency department inpatient collaborative to reduce unnecessary bronchiolitis care. *Pediatrics*. 2018;141(2):e20170830. doi:10.1542/peds.2017.0830
26. Lipshaw MJ, Vukovic AA, Dean P, et al. High-flow nasal cannula in bronchiolitis at a pediatric emergency department: trends and outcomes. *Hosp Pediatr*. 2021;11(2):119-125.
27. Yurtseven A, Turan C, Erseven E, Saz EU. Comparison of heated humidified high-flow nasal cannula flow rates (1-L·kg⁻¹·min⁻¹ vs 2-L·kg⁻¹·min⁻¹) in the management of acute bronchiolitis. *Pediatr Pulmonol*. 2019;54:894-900.
28. Milési C, Pierre AF, Deho A, et al. A multicenter randomized controlled trial of a 3-L/kg/min versus 2-L/kg/min high-flow nasal cannula flow rate in young infants with severe viral bronchiolitis (TRAMONTANE 2). *Intensive Care Med*. 2018;44(11):1870-1878.
29. Pham TM, 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(7):713-720.
30. Hough JL, Pham TM, Schibler A. Physiologic effect of high-flow nasal cannula in infants with bronchiolitis. *Pediatr Crit Care Med*. 2014;15(5):e214-e219.
31. González Martínez F, González Sánchez MI, Pérez-Moreno J, Toledo del Castillo B, Rodríguez Fernández R. What is the optimal flow on starting high-flow oxygen therapy for bronchiolitis treatment in paediatric wards? *An Pediatr*. 2019;91:112-119.
32. Weiler T, Kamerkar A, Hotz J, Ross PA, Newth CJL, Khemani RG. The relationship between high flow nasal cannula flow rate and effort of breathing in children. *J Pediatr*. 2017;189:66-71.
33. Milesi C, Requirand A, Douillard A, et al. Assessment of peak inspiratory flow in young infants with acute viral bronchiolitis: physiological basis for initial flow setting in patients supported with high-flow nasal cannula. *J Pediatr*. 2021;231:239-245.
34. Papoff P, Caresta E, Luciani S, et al. The starting rate for high-flow nasal cannula oxygen therapy in infants with bronchiolitis: is clinical judgment enough? *Pediatr Pulmonol*. 2021;56(8):2611-2620.
35. Riese J, Porter T, Fierce J, Riese A, Richardson T, Alverson BK. Clinical outcomes of bronchiolitis after implementation of a general ward high flow nasal cannula guideline. *Hosp Pediatr*. 2017;7(4):197-203.
36. Coon ER, Stoddard G, Brady PW. Intensive care unit utilization after adoption of a ward-based high-flow nasal cannula protocol. *J Hosp Med*. 2020;15(6):325-330.
37. Andrews C, Maxwell SL, Kerns E, McCulloh R, Alverson B. The association of seasonality with resource use in a large national cohort of infants with bronchiolitis. *Hosp Pediatr*. 2021;11(2):126-134.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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