

# De-escalation of High-flow Respiratory Support for Children Admitted with Bronchiolitis: A Quality Improvement Initiative

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## Abstract

**Introduction:** Bronchiolitis is the most common cause for hospitalization in the first year of life, with hypoxemia and acute respiratory failure as major determinants leading to hospitalization. In addition, the lack of existing guidelines for weaning and discontinuing supplemental oxygen, including high-flow nasal cannula, may contribute to prolonged hospitalization and increased resource utilization. **Methods:** This single-center quality improvement initiative assessed the effect of implementing a standardized care process for weaning and discontinuing high-flow oxygen for patients hospitalized with bronchiolitis. Patients aged 1–24 months with bronchiolitis admitted to the general wards or ICU step-down unit from February 1, 2018, and January 31, 2020 were included in the study. Primary outcomes included length of stay and time on supplemental oxygen, with time on high-flow oxygen and length of time in ICU step-down unit as secondary outcomes. Balancing measures included transfer rate to Pediatric Intensive Care Unit, intubation rate, 7- and 30-day readmission rates, and 7- and 30-day ED visits after discharge. **Results:** Following the standardized care process implementation, the mean length of stay decreased from 60.7 hours to 46.7 hours ( $P < 0.01$ ). In addition, the mean time on any supplemental oxygen decreased by 47% ( $P < 0.01$ ), the mean time on high-flow oxygen decreased by 45% ( $P < 0.01$ ), and the mean time in the ICU step-down unit decreased by 27% ( $P < 0.01$ ). Balancing measures remained unchanged with no statistically significant differences. **Conclusion:** Implementing a standardized care process for weaning and discontinuing high-flow oxygen may reduce the length of stay and resource utilization for patients hospitalized with bronchiolitis. (*Pediatr Qual Saf* 2022;7:e534; doi: 10.1097/pq9.000000000000534; Published online March 30, 2022.)

## INTRODUCTION

Bronchiolitis is a viral lower respiratory tract infection characterized by acute inflammation, edema, and increased mucus production in the bronchioles that affects infants and children in the first two years of life.<sup>1,2</sup> While most children have mild symptoms, many can progress to respiratory distress and respiratory failure



requiring hospitalization and ventilatory support. Bronchiolitis is the leading cause of infant hospitalization in the first 12 months of life.<sup>1,2</sup> Approximately 100,000 children with bronchiolitis are admitted each year in the United States, with an estimated annual cost of \$1.73 billion.<sup>1,2</sup> Treatment for bronchiolitis, based on the most recent clinical practice guidelines provided by the American Academy of Pediatrics, remains predominantly supportive with nasal suctioning, intravenous fluids and/or enteral feeds, and supplemental oxygen.<sup>2</sup> Hypoxemia and acute respiratory failure are major determinants leading to hospitalization in patients with bronchiolitis and often lead to prolonged hospitalization and rising costs of care.<sup>3–6</sup>

Among the more severely ill patients who present with respiratory failure, the use of high-flow nasal cannula (HFNC) therapy has emerged as a noninvasive method to provide positive airway pressure, reduce work of breathing, and potentially decrease the need for intubation.<sup>7–10</sup> However, the efficacy of HFNC is controversial. Several studies have demonstrated reduced LOS,<sup>11</sup> decreased rate of ICU admission,<sup>12</sup> and reduced intubation rate.<sup>8–10,13</sup> Other studies have demonstrated no improvement in intubation rate or LOS<sup>14,15</sup> and instead showed an increased ICU admission rate<sup>14,15</sup>

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and higher resource utilization.<sup>16</sup> These data suggest that HFNC has become over-utilized in some patients who will not benefit from it, likely due to a lack of clear criteria for initiation of HFNC.<sup>17,18</sup> Additionally, little medical evidence exists to guide the weaning of supplemental oxygen, leading to significant variability in clinical care.<sup>18–20</sup> This is further complicated by subjective evaluation of patients with bronchiolitis due to rapidly changing physical examination findings and poor validity of measurement instruments such as respiratory distress index.<sup>21</sup>

The combination of limited evidence-based interventions, subjective evaluation, and no established standard of care for de-escalation of support contributes to overtreatment and increased resource utilization in the care of patients with bronchiolitis. This study sought to address this gap in current practice by creating and implementing a standardized care process for de-escalating respiratory support in bronchiolitis to promote high-value care.

At our institution, the mean length of stay (LOS) for patients admitted with bronchiolitis from Feb 2018 to Jan 2019 was 60.7 hours (2.5 days), higher than the national average of 55.2 hours (2.3 days).<sup>22</sup> S-chart evaluation of LOS revealed seasonal special cause variation, demonstrating a significant variability in our system. In addition, a wide variability between control limits was also present when evaluating time on supplemental oxygen, time on HFNC, and duration in ICU step-down unit. Based on these data, our primary specific aim was to decrease the LOS of pediatric patients admitted with bronchiolitis by 10% within 12 months (February 1, 2019 to January 31, 2020). This aim was defined as a decrease in LOS from 60 to 54 hours, using the national average of 55 hours according to the Pediatric Health Information System at the time of implementation as a benchmark.<sup>22</sup> A second specific aim was to decrease the duration of supplemental oxygen therapy, including both simple nasal cannula and HFNC, in pediatric patients hospitalized with bronchiolitis by 10% within 12 months (February 1, 2019 – January 31, 2020).

## METHODS

### *Setting, Study Design, and Study Population*

This study was conducted at Children's of Alabama (CoA), a quaternary care freestanding children's hospital with 332 inpatient beds. The ICU step-down unit, managed by the pediatric hospital medicine service, comprises 25 beds and is utilized for patients who require cardiorespiratory monitoring or HFNC. This unit is often at or near capacity, affecting patient placement and hospital throughput; patients admitted with less severe bronchiolitis and not requiring HFNC are placed on non-monitored general ward floors. The hospital has approximately 15,000 admissions per year,

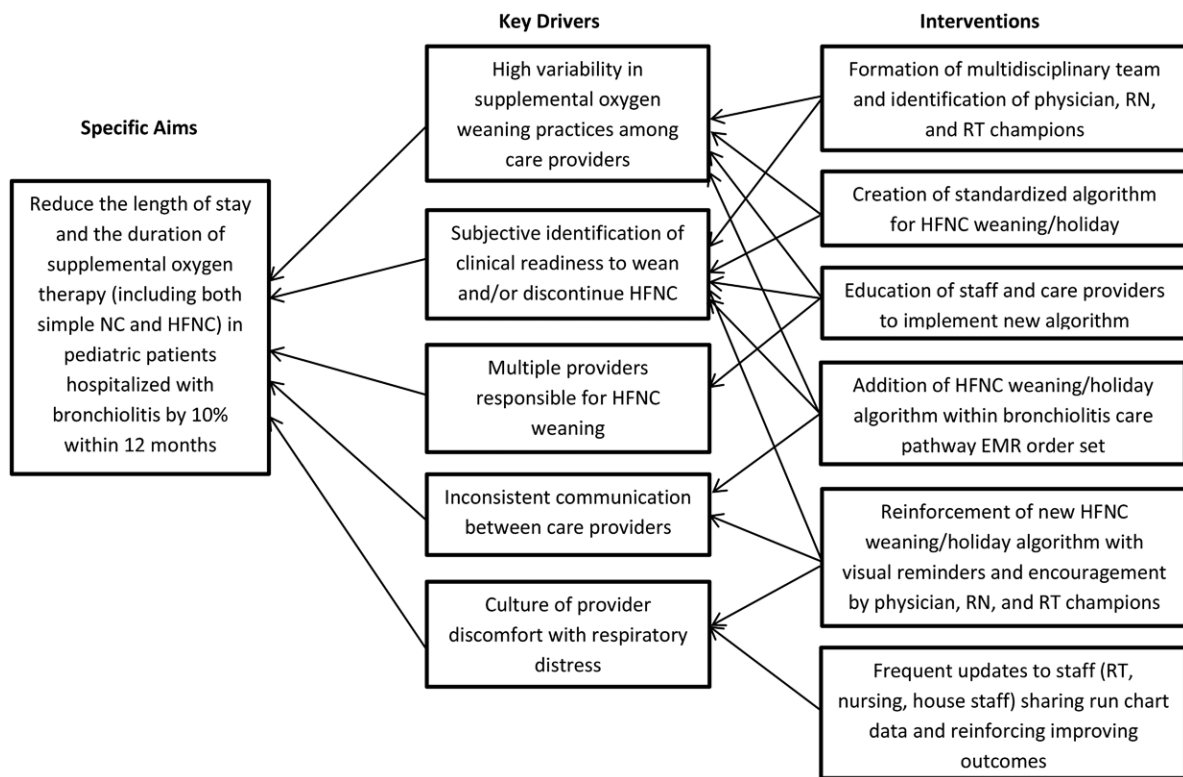
with over 500 admissions per year due to bronchiolitis. To better understand the existing process and to identify potential areas for improvement, baseline data were collected and evaluated for overall LOS, time on any supplemental oxygen (including both simple nasal cannula and HFNC), time on HFNC, and LOS in the ICU step-down unit for patients admitted with bronchiolitis in the 12 months before project initiation (February 2018-January 2019). A multidisciplinary team composed of pediatric hospitalists, respiratory therapy leadership, nursing leadership, bedside nurse champions, and physician/house staff representatives evaluated the baseline data and identified key drivers of current practices (Fig. 1). Our team hypothesized that variability in supplemental oxygen weaning led to prolonged time on supplemental oxygen, subsequently impacting LOS. Therefore, we identified standardization of HFNC weaning as the primary intervention to decrease the LOS and time on supplemental oxygen for patients hospitalized with bronchiolitis.

### *Eligibility Criteria/exclusion Criteria*

The patient population included patients aged 1–24 months with clinical symptoms of bronchiolitis admitted on our bronchiolitis clinical pathway (BCP). Criteria excluding patients from the BCP were age younger than 1 month, history of chronic lung disease including bronchopulmonary dysplasia, history of complicating chronic illness such as stridor or anatomic airway defects, tracheostomy, cyanotic heart disease or cardiac disease requiring medication, home oxygen use, severe neuromuscular disease, or immunodeficiency. We did not specifically exclude premature infants; however, exclusion criteria included infants with chronic lung disease or supplemental oxygen requirement beyond 36 weeks corrected gestation. Only patients requiring HFNC were eligible for the interventions; however, we collected data on all patients on the BCP to compare to baseline data. Patients admitted to the Pediatric Intensive Care Unit (PICU) were eligible to be included on the BCP once they transferred out of the PICU; data collected for these patients included their entire hospitalization.

### *Data Collection*

We obtained and evaluated data on patient demographics (Table 1), clinical outcomes (Table 2), and resource utilization outcomes, including respiratory charges such as hourly charges for high-flow oxygen and simple nasal cannula oxygen. Ongoing data were collected and evaluated throughout multiple Plan-Do-Study-Act (PDSA) cycles and plotted on X-bar statistical process control charts. The analysis included all eligible patients throughout the baseline and intervention cycles. Following institutional review board standards at our institution, this study was IRB-approved as quality improvement and not human subjects research.



**Fig. 1.** Key driver diagram for reducing LOS and duration of HFNC. NC, nasal cannula; RN, registered nurse; RT, respiratory therapist.

**Table 1. Characteristics of Hospitalized Infants on Bronchiolitis Pathway**

Characteristic	Pre-intervention (n = 451)	Post-intervention (n = 554)	P
Age			
Average age (mo)	8.23	8.69	0.23
Average gestational age (wk)	38.29	37.82	0.01
Gender, n (%)			
Men	287 (64)	325 (59)	0.10
Women	164 (36)	229 (41)	
Race/Ethnicity, n (%)			
White	241 (53)	323 (58)	0.20
Black	186 (41)	214 (39)	
Hispanic	21 (5)	12 (2)	
Asian	2 (<1)	2 (<1)	
Other	1 (<1)	3 (1)	
Tobacco exposure, n (%)			
Yes	115 (25)	144 (26)	0.98
No	246 (55)	299 (54)	
Unknown	90 (20)	111 (20)	
Insurance, n (%)			
Public	316 (70)	387 (70)	0.88
Private	125 (28)	157 (28)	
Self-pay	10 (2)	10 (2)	

**Outcome Measures**

Primary outcomes included mean LOS and mean duration on any supplemental oxygen therapy, measured in hours. Secondary outcomes included mean duration on HFNC and LOS in ICU step-down unit, measured in hours. Balancing measures included transfer to PICU, intubation rate, and 7- and 30- day readmission rate, and 7- and 30- day ED visits after discharge, measured as monthly percentages.

**Interventions**

The PDSA cycle, based on the Institute for Healthcare Improvement’s Model for Improvement,<sup>2,3</sup> consisted of implementing an algorithm for weaning and discontinuing HFNC and trialing on room air, referred to as a high-flow holiday (HFH). The patient’s current HFNC requirement and respiratory severity score directed this algorithm. HFH could be trialed up to twice daily at any time (typically 0400, 1600) in patients meeting the

Table 2. Primary and Secondary Outcomes and Balancing Measures

Variable	Pre-intervention	Post-intervention	P
Primary outcomes			
Length of stay (h)	60.68	46.72	<0.01
Time on supplemental oxygen (h)	57.80	30.54	<0.01
Secondary outcomes			
Time on high-flow oxygen (h)	52.89	28.93	<0.01
Time in ICU step-down unit (h)	56.54	38.14	<0.01
Balancing measures			
PICU transfer rate, n (%)	12 (2.66%)	23 (4.16%)	0.23
Intubation rate, n (%)	4 (0.89%)	3 (0.54%)	0.71
7-day readmission rate, n (%)	8 (1.77%)	11 (1.99%)	0.18
30-day readmission rate, n (%)	22 (4.88%)	21 (3.79%)	0.44
7-day ED visit rate, n (%)	12 (2.66%)	8 (1.44%)	0.07
30-day ED visit rate, n (%)	17 (3.77%)	22 (3.97%)	1.00

criteria but typically did not occur in newly admitted patients until they had been monitored at least 4 hours post-admission (Fig. 2). The components of the already existing bronchiolitis severity scoring system at CoA include respiratory rate, work of breathing, behavior, and auscultation, with scores of 0–4 indicating mild disease, 5–8 indicating moderate disease, and 9–12 indicating severe disease. Although respiratory scoring is inconsistent,<sup>21</sup> utilization of a scoring system provided some

objectivity for assessment and communication between providers. Therefore, we selected this metric as the initial intervention because, before project implementation, HFNC weaning was at the discretion of the bedside respiratory therapist and/or medical team.

In addition, patients typically slowly transitioned from HFNC to simple nasal cannula, which was similarly slowly and subjectively weaned. We identified this variable weaning process and transition from HFNC to

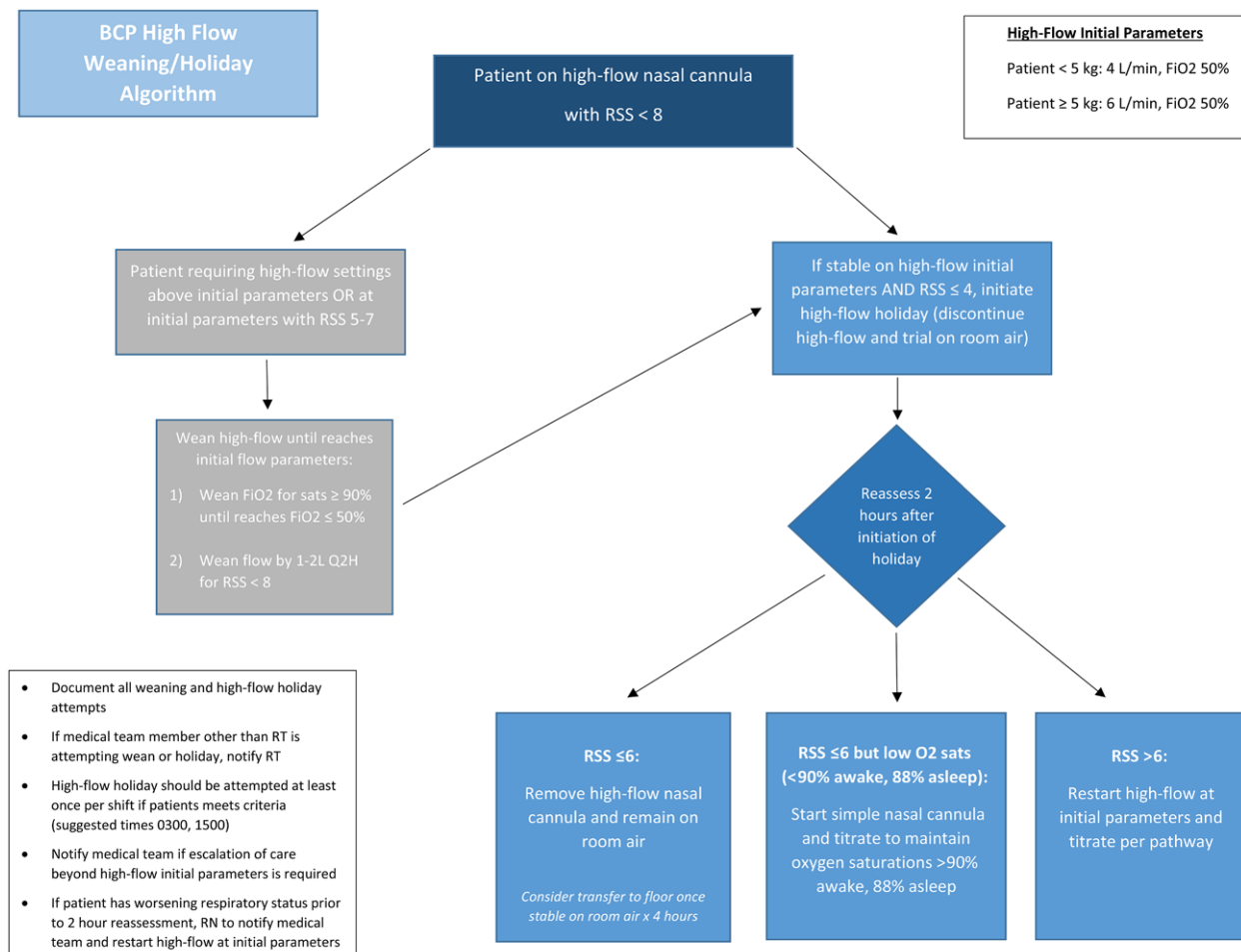


Fig. 2. High-flow holiday Flow Chart. BCP, Bronchiolitis Clinical Pathway; RT, Respiratory Therapy; RN, Registered Nurse.

low-flow oxygen as a potential unnecessary step contributing to prolonged supplemental oxygen time and extending LOS. To address the change in hospital culture and existing HFNC weaning practices, we included educating staff and care providers and displaying the laminated chart with the algorithm at every nursing workstation (located just outside patient rooms) in the first cycle. Although education alone is a less effective intervention to produce meaningful and sustained change,<sup>24</sup> we started with this step while working on future more robust interventions.

As the first cycle relied on education, and staff initially was hesitant to wean and discontinue HFNC more quickly than was previously done, the subsequent PDSA cycles included more robust interventions such as including the algorithm into hospital policy (PDSA cycle 2) and as a pre-checked order within the bronchiolitis order set in the electronic medical record (PDSA cycle 3). These additional cycles occurred after several months of data demonstrated that outcomes had not worsened following the initial intervention and as staff became more comfortable with the HFNC weaning/holiday algorithm.

### Statistical Analysis

The data were displayed using a statistical process X-bar control chart utilizing the Institute for Healthcare Improvement rules for assessing special cause variation. Specifically, we used the following rules: (1) a point outside the control limits, (2) 6 consecutive points all increasing/decreasing, (3) two out of three points in the outer third deviation of the chart, and (4) eight or more consecutive points above/below the mean/centerline. The upper and lower control limits represented the data at three standard deviations. Once the data fit the criteria for a significant special cause variation in a trend, we re-analyzed the data to create a new mean and control limits. Process control charts were completed using QI Macros 2016. Two-tailed student's T-testing assuming unequal variances for pre- and post- data for the outcome measures was performed with SAS, version 9.4.

## RESULTS

A total of 1005 patients were admitted to the BCP from February 2018 to February 2020, with 554 patients admitted after project implementation in February 2019. Table 1 provides the patients' demographics and clinical characteristics. Six hundred thirty-six (636) patients received any supplemental oxygen, with 442 patients receiving HFNC. After implementation of interventions to standardize HFNC weaning/discontinuation, there was a 23% reduction in mean LOS from a baseline of 60.7 hours (SD = 58.7) to 46.7 hours (SD = 37.7,  $t(1003)=4.56$ ,  $P < 0.01$ ) (Fig. 3). In addition, there was a 47% reduction in the mean time on any supplemental oxygen from a baseline of 57.8 hours (SD = 57.8)

to 30.5 hours (SD = 28,  $t(634)=7.66$ ,  $P < 0.01$ ) (Fig. 3). The mean time on HFNC decreased by 45% from a baseline of 52.9 hours (SD = 42.5) to 28.9 hours (SD = 22.7,  $t(440)=7.67$ ,  $p < 0.01$ ) (Fig. 4). The mean time in ICU step-down unit decreased by 27% from a baseline of 56.5 hours (SD = 47.8) to 38.1 hours (SD = 26.8,  $t(492)=5.46$ ,  $p < 0.01$ ) (Fig. 4). Additionally, there was a significant decrease in variation over time and tightening of control limits, indicating a more stable process. These control charts demonstrate rapid changes in outcomes, with the greatest change being seen with the initial intervention of implementing the HFH weaning/holiday algorithm likely secondary to the enthusiasm and efforts of a primary stakeholder in our lead respiratory therapist. Overall, there were 245 holiday trials, with 212 patients requiring no further supplemental oxygen; 6 patients who failed the holiday required replacing their HFNC, and 27 patients who developed hypoxemia required transition to low-flow oxygen.

Balancing measures remained stable with no statistically significant differences (Table 2). A review of resource utilization outcomes demonstrated decreased respiratory charges due to reduced supplemental oxygen usage. The mean respiratory charge (based on hourly charges for HFNC and simple nasal cannula oxygen) per patient pre-intervention was \$2428.99. The post-intervention was \$1486.36, with a mean savings of \$942.63 per patient.

## DISCUSSION

This quality improvement initiative demonstrated that standardizing weaning of supplemental oxygen therapy was associated with decreased LOS and time on supplemental oxygen. The mean LOS following the interventions was 46.7 hours (1.8 days), compared with 2.4 days<sup>1,2</sup> or 3.3 days<sup>25</sup> previously reported in the literature. There were no significant differences in patient population pre- and post-intervention other than a younger average gestational age in post-intervention patients, which likely was due to a revision of the inclusion/exclusion criteria for the BCP at the time of intervention, specifically no longer excluding premature infants from being placed on the BCP.

Currently, there is limited and conflicting evidence for improved clinical outcomes in HFNC use in the treatment of bronchiolitis. A systematic review by Lin et al.<sup>26</sup> of nine randomized control trials assessing HFNC use in bronchiolitis demonstrated a significant reduction in the incidence of treatment failure in the high-flow group. Otherwise, there were no significant differences in LOS, length of oxygen supplementation, transfer to intensive care unit, intubation rate, or adverse events. Multiple studies have demonstrated its safety for use outside of intensive care units<sup>11,13,27</sup>; however, its increasing utilization has not consistently demonstrated improved outcomes on LOS and time on supplemental oxygen,<sup>28</sup> which

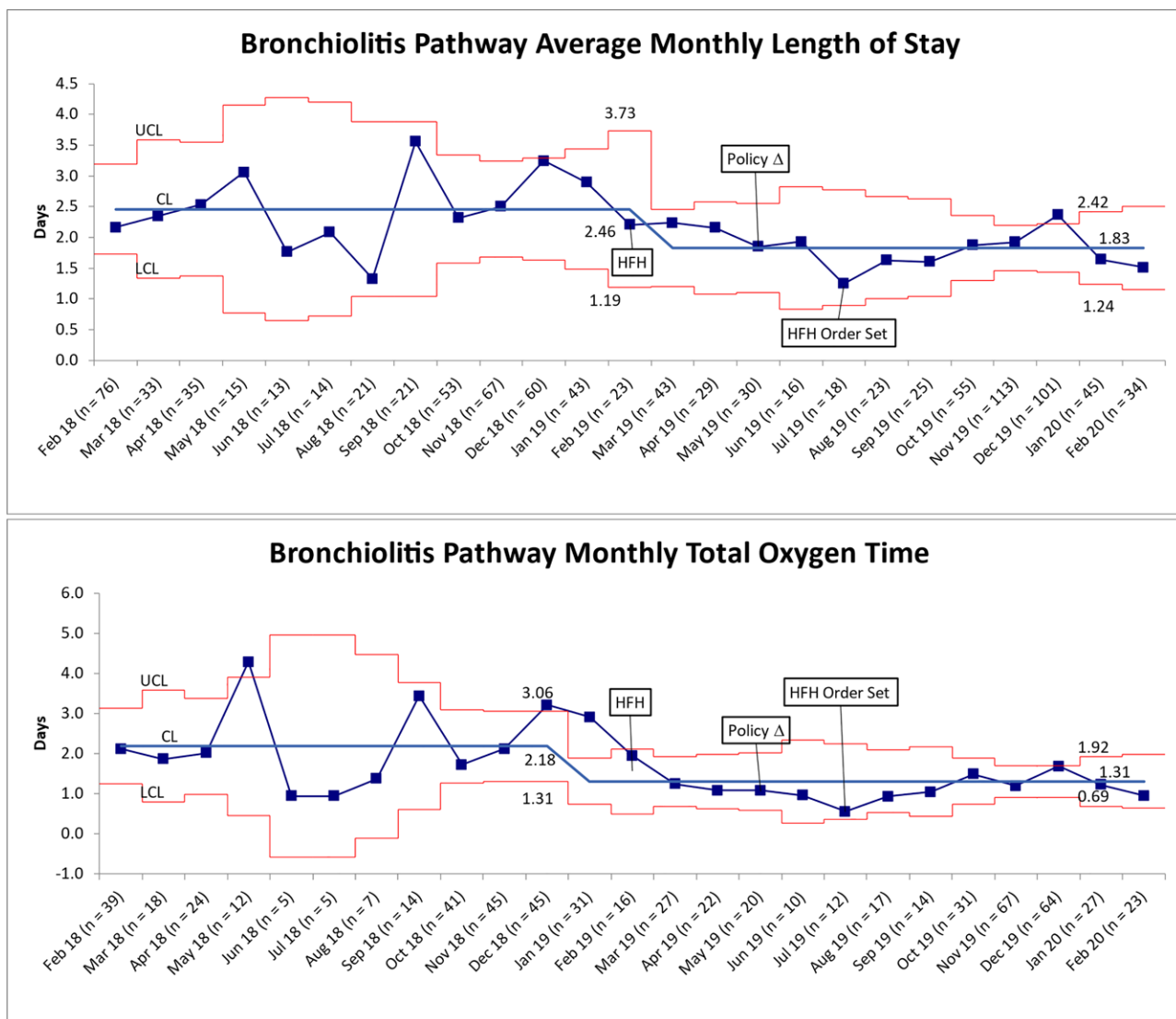


Fig. 3. X-bar charts for primary outcomes. Δ, Change

may be related to variability in care in part due to lack of guidelines for de-escalation of care.

Multiple factors contributed to the success of our QI intervention of implementing the HFNC weaning/holiday algorithm, including multidisciplinary collaboration, with strong buy-in from respiratory leadership and all champions encouraging bedside discussion on rounds helping with the adoption of this change. In addition, subsequent incorporation of the algorithm as part of a care pathway within electronic medical record order sets helped decrease variation in ordering practices and improve adherence to the guidelines.<sup>29-31</sup> Additional factors contributing to culture change and the successful adoption of the changes included visible protocol reminders at the bedside and regular updates to staff (respiratory therapy, nursing, and house staff) with charts displaying improved outcomes over time.

One barrier to early adoption was observed during cycle 1, with the discomfort of bedside medical staff during

the observation period following a HFH and subsequent reinitiation of HFNC despite patients not meeting the criteria established in the algorithm. This occurrence became less common over time as providers became more accustomed to the practice of discontinuing HFNC without a transition to a simple nasal cannula. The frequent updates regarding our improving outcomes reinforced this to all involved staff.

A second related barrier to adopting new practices is the culture among medical providers to treat any tachypnea or increased work of breathing with supplemental oxygen, even in patients without hypoxemia. As HFNC usage has increased across the country, it is possible providers have become more uncomfortable with mild-moderate respiratory distress, and thus contributed to overtreatment and increased utilization. Additionally, there are no nationally agreed-upon metrics for implementing HFNC, which likely leads to variability between providers. Addressing this paradox, especially with an emphasis on educating

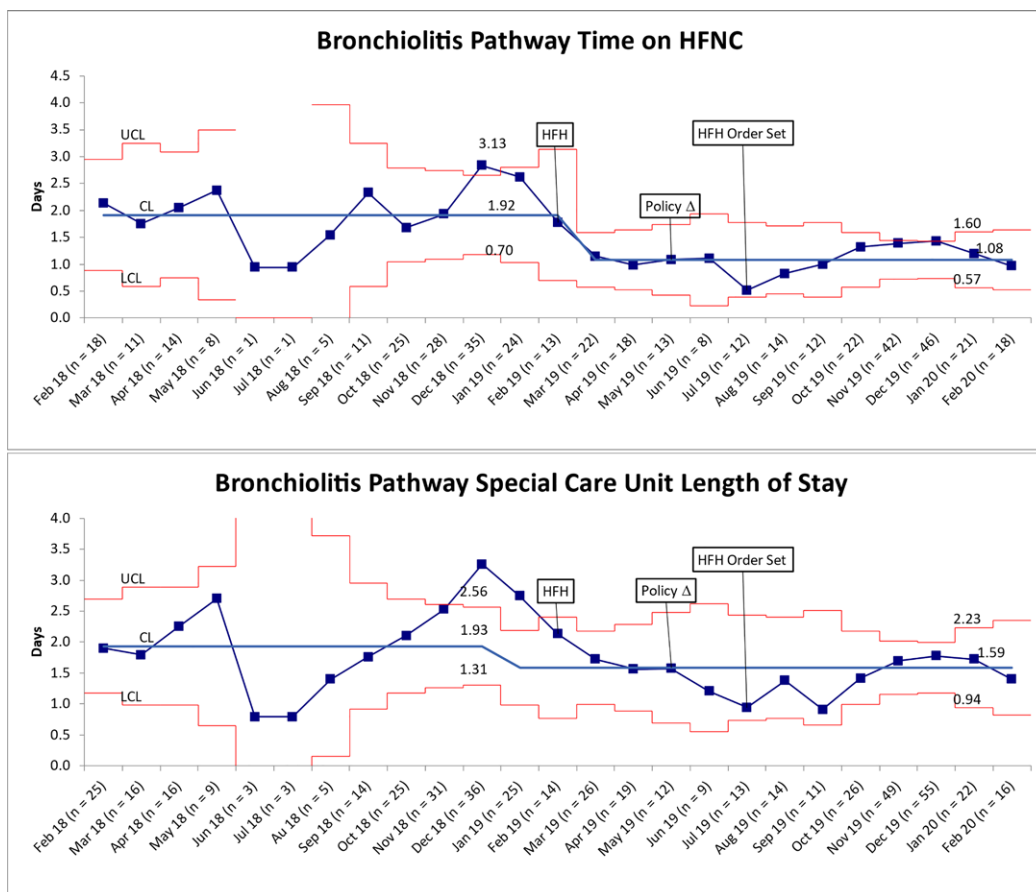


Fig. 4. X-bar charts for secondary outcomes. Δ, Change

medical trainees, may help future quality improvement efforts in bronchiolitis care, especially those focusing on value-based care. Our attempts to address this barrier included discussions about the indications for various respiratory therapies, including supplemental oxygen, and encouragement of providers to follow the established algorithm, which incorporated multiple aspects of clinical status in decision-making instead of just increased work of breathing.

Overutilization in bronchiolitis has become an increasingly discussed topic, as a growing focus on value-based care highlights the importance of reducing unnecessary care. One multicenter collaborative<sup>32</sup> focused on discontinuation of unnecessary therapies for bronchiolitis in community hospital sites and successfully achieved a 68% reduction in steroid use and 29% reduction in bronchodilator use. Another initiative by Mittal et al<sup>3</sup> demonstrated successful use of QI methodology to reduce supplemental oxygen use through judicious use of intermittent pulse oximetry in nonhypoxemic patients with bronchiolitis. These studies highlight the potential for further quality improvement work in minimizing waste in healthcare settings and indicate that collaboration, combined with the application of evidence-based best practices, can help enable cultural and behavioral shifts to reduce unnecessary

care.<sup>33</sup> High variability in care can contribute to a lack of evidence-based practice and increasing healthcare costs. The development of protocols and clinical pathways has led to decreased variation and improved resource utilization.<sup>34</sup> A prior study by Gc et al. demonstrated that the use of HFNC as initial therapy was unlikely to be cost-saving compared with standard oxygen therapy with HFNC as rescue therapy for respiratory failure in infants with bronchiolitis and found that use of initial HFNC was associated with a \$420 increased cost per infant.<sup>35</sup> Similarly, in our study, reduced supplemental oxygen usage was associated with decreased respiratory charges.

**Limitations**

Several limitations to this study may have affected the above findings. Year-to-year variation in viruses and severity of illness may have impacted the results, as declining severity of bronchiolitis could be a factor in the reduced LOS. However, even if seasonal variation contributed to LOS reduction, this initiative improved variation for all primary and secondary outcomes. Another potential limitation includes not adjusting for other patient factors that impact the LOS, such as feeding status and social dynamics; however, these factors likely were also present in baseline data and would not be expected to vary

significantly from year to year. Data collection (both pre-intervention and post-intervention) included all patients admitted on the BCP and not stratified between those requiring no supplemental oxygen versus HFNC or simple nasal cannula alone. This stratification may be a potential next step to address in future efforts to identify differences in outcomes based on patient subsets. Our study was a single-center study and would need to be done at other institutions to ensure generalizability. Lastly, due to the COVID-19 pandemic, the number of admissions due to bronchiolitis significantly decreased from March 2020 onward, limiting the ability to assess the sustainability of the interventions.

## CONCLUSION

Overall, implementing a standardized process for weaning and discontinuing supplemental oxygen was associated with a reduction in mean LOS and time on supplemental oxygen for patients hospitalized with bronchiolitis without increasing adverse events, thereby demonstrating the potential for safely minimizing resource utilization. In addition, this standardized process has become incorporated into the workflow and, as part of an electronic order set in the electronic medical record, should remain sustainable over time. The next steps include collaborating with PICU staff to expand HFNC weaning/holiday guidelines into the intensive care setting and implementing recommendations for feeding and enteral nutrition for patients on HFNC to optimize care.

## DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

## REFERENCES

- Hasegawa K, Tsugawa Y, Brown DF, et al. Trends in bronchiolitis hospitalizations in the United States, 2000–2009. *Pediatrics*. 2013;132:28–36.
- Ralston SL, Lieberthal AS, Meissner HC, et al; American Academy of Pediatrics. Clinical practice guideline: the diagnosis, management, and prevention of bronchiolitis. *Pediatrics*. 2014;134:e1474–e1502.
- Mittal S, Marlowe L, Blakeslee S, et al. Successful use of quality improvement methodology to reduce inpatient length of stay in bronchiolitis through judicious use of intermittent pulse oximetry. *Hosp Pediatr*. 2019;9:73–78.
- McCulloh R, Koster M, Ralston S, et al. Use of intermittent vs continuous pulse oximetry for nonhypoxemic infants and young children hospitalized for bronchiolitis: A randomized clinical trial. *JAMA Pediatr*. 2015;169:898–904.
- Unger S, Cunningham S. Effect of oxygen supplementation on length of stay for infants hospitalized with acute viral bronchiolitis. *Pediatrics*. 2008;121:470–475.
- Weisgerber MC, Lye PS, Li SH, et al. Factors predicting prolonged hospital stay for infants with bronchiolitis. *J Hosp Med*. 2011;6:264–270.
- Lee JH, Rehder KJ, Williford L, et al. Use of high flow nasal cannula in critically ill infants, children, and adults: a critical review of the literature. *Intensive Care Med*. 2013;39:247–257.
- McKiernan C, Chua LC, Visintainer PF, et al. High flow nasal cannulae therapy in infants with bronchiolitis. *J Pediatr*. 2010;156:634–638.
- Schibler A, Pham TM, Dunster KR, et al. Reduced intubation rates for infants after introduction of high-flow nasal prong oxygen delivery. *Intensive Care Med*. 2011;37:847–852.
- Wing R, James C, Maranda LS, et al. Use of high-flow nasal cannula support in the emergency department reduces the need for intubation in pediatric acute respiratory insufficiency. *Pediatr Emerg Care*. 2012;28:1117–1123.
- Riese J, Fierce J, Riese A, et al. Effect of a hospital-wide high-flow nasal cannula protocol on clinical outcomes and resource utilization of bronchiolitis patients admitted to the PICU. *Hosp Pediatr*. 2015;5:613–618.
- 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;389:930–939.
- Franklin D, Fraser JF, Schibler A. Respiratory support for infants with bronchiolitis, a narrative review of the literature. *Paediatr Respir Rev*. 2019;30:16–24.
- Garland H, Gunz AC, Miller MR, et al. High-flow nasal cannula implementation has not reduced intubation rates for bronchiolitis in Canada. *Paediatr Child Health*. 2021;26:e194–e198.
- Sklansky DJ, Mahant S. Should the pendulum swing back? More transfers to the ICU after implementing ward-based high-flow nasal cannula initiation protocols for bronchiolitis. *J Hosp Med*. 2020;15:381–382.
- 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;15:325–330.
- de Benedictis FM. The Effectiveness of high-flow oxygen therapy and the fascinating song of the sirens. *JAMA Pediatr*. 2019;173:125–126.
- Piper L, Stalets EL, Statile AM. Clinical practice update: High flow nasal cannula therapy for bronchiolitis outside the ICU in Infants. *J Hosp Med*. 2019;14:E1–E3.
- Kawaguchi A, Garros D, Joffe A, et al. Variation in practice related to the use of high flow nasal cannula in Critically Ill Children. *Pediatr Crit Care Med*. 2020;21:e228–e235.
- Pierce HC, Mansbach JM, Fisher ES, et al. Variability of intensive care management for children with bronchiolitis. *Hosp Pediatr*. 2015;5:175–184.
- Fernandes RM, Plint AC, Terwee CB, et al. Validity of bronchiolitis outcome measures. *Pediatrics*. 2015;135:e1399–e1408.
- Data for this study were obtained from the Pediatric Health Information System (PHIS), an administrative database that contains inpatient, emergency department, ambulatory surgery and observation encounter-level data from over 50 not-for-profit, tertiary care pediatric hospitals in the United States. These hospitals are affiliated with the Children's Hospital Association (Lenexa, KS). Data quality and reliability are assured through a joint effort between the Children's Hospital Association and participating hospitals. For the purposes of external benchmarking, participating hospitals provide discharge/encounter data including demographics, diagnoses, and procedures. Nearly all of these hospitals also submit resource utilization data (eg, pharmaceuticals, imaging, and laboratory) into PHIS. Data are de-identified at the time of data submission, and data are subjected to a number of reliability and validity checks before being included in the database.
- Langley GL, Moen R, Nolan KM, Nolan TW, Normal CL, Provost LP. *The Improvement Guide: A Practical Approach to Enhancing Organizational Performance*. 2nd ed. San Francisco, Calif.: Jossey-Bass Publishers; 2009.
- Doughty P. Contextual considerations for behavior change: Intervention/method selection. In G.G. Gilbert and R.G. Sawyer and E.B. McNeill (Eds.). *Health Education: Creating Strategies for School and Community Health*. 4th ed. Burlington, Mass.: Jones & Bartlett Learning; 2010: 47–96. Retrieved from [http://samples.jpub.com/9780763759292/59292\\_CH03\\_047\\_096.pdf](http://samples.jpub.com/9780763759292/59292_CH03_047_096.pdf)
- Pelletier AJ, Mansbach JM, Camargo CA Jr. Direct medical costs of bronchiolitis hospitalizations in the United States. *Pediatrics*. 2006;118:2418–2423.
- Lin J, Zhang Y, Xiong L, et al. High-flow nasal cannula therapy for children with bronchiolitis: a systematic review and meta-analysis. *Arch Dis Child*. 2019;104:564–576.



27. 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;378:1121–1131.
28. Riese J, Porter T, Fierce J, et al. Clinical outcomes of bronchiolitis after implementation of a general ward high flow nasal cannula guideline. *Hosp Pediatr.* 2017;7:197–203.
29. Probst CA, Shaffer VA, Chan YR. The effect of defaults in an electronic health record on laboratory test ordering practices for pediatric patients. *Health Psychol.* 2013;32:995–1002.
30. Jacobs BR, Hart KW, Rucker DW. Reduction in clinical variance using targeted design changes in computerized provider order entry (CPOE) order sets: impact on hospitalized children with acute asthma exacerbation. *Appl Clin Inform.* 2012;3:52–63.
31. Van Cleve WC, Christakis DA. Unnecessary care for bronchiolitis decreases with increasing inpatient prevalence of bronchiolitis. *Pediatrics.* 2011;128:e1106–e1112.
32. Ralston SL, Garber MD, Rice-Conboy E, et al. A multicenter collaborative to reduce unnecessary care in inpatient bronchiolitis. *Pediatrics.* 2016;137:1–9.
33. Schwartz SP, Rehder KJ. Quality improvement in pediatrics: past, present, and future. *Pediatr Res.* 2017;81:156–161.
34. LeCleir B, Jurecko L, Davis AT, et al. Implementing an oxygen supplementation and monitoring protocol on inpatient pediatric bronchiolitis: an exercise in deimplementation. *Int J Pediatr.* 2017;2017:3169098.
35. Gc VS, Franklin D, Whitty JA, et al. First-line oxygen therapy with high-flow in bronchiolitis is not cost saving for the health service. *Arch Dis Child.* 2020;105:975–980.