

Implementation of a High-Flow Nasal Cannula Management Protocol in the Pediatric ICU

Rachel J Peterson, Daniel O Hassumani, Acrista J Hole, James E Slaven, Alvaro J Tori, and Samer Abu-Sultaneh

BACKGROUND: High-flow nasal cannula (HFNC) therapy is a respiratory modality that has been adopted to support pediatric patients with bronchiolitis. There is no standardized protocol for initiation, escalation, or weaning of HFNC in the pediatric ICU. The aim of this respiratory therapist (RT)-driven quality improvement management protocol was to decrease duration of HFNC. **METHODS:** An RT-driven HFNC management protocol based on an objective respiratory score was implemented in 2017 at a quaternary care children's hospital. Subjects included children less than 2 y old admitted to the pediatric ICU with bronchiolitis. All subjects needing HFNC were scored and placed within the protocol as appropriate for age, then weaned or escalated per the scoring tool. Comparison to a pre-intervention control group was performed. Average HFNC duration per subject was used as the primary outcome measure. Protocol compliance was used as a process measure. Noninvasive ventilation use, intubation rate, and 30-d pediatric ICU readmission rate were used as balancing measures. RT satisfaction with HFNC management before and after protocol implementation were measured. **RESULTS:** Protocol compliance was sustainable and above the goal of 80% after 4 months of protocol implementation. HFNC duration decreased from 2.5 d to 2 days for each subject during planning and then to 1.8 d after protocol implementation. Length of stay (LOS) in the pediatric ICU and hospital LOS decreased from 2.6 d to 2.1 d and from 5.7 d to 4.7 d after protocol implementation, respectively. The use of noninvasive ventilation and the rate of intubation did not change significantly. RTs reported increased involvement in HFNC management decisions and appropriateness on how quickly the team weaned HFNC. **CONCLUSIONS:** An RT-driven HFNC management protocol was safely implemented in a pediatric ICU and decreased HFNC duration, pediatric ICU LOS, and hospital LOS. It allows the RT to work independently to the highest extent of their scope of practice, leading to improvement in RT job satisfaction. *Key words:* bronchiolitis; high-flow nasal cannula; interdisciplinary studies; noninvasive ventilation; pediatric intensive care; quality improvement. [Respir Care 2021;66(4):591–599. © 2021 Daedalus Enterprises]

Introduction

Bronchiolitis is a leading cause of health care utilization for infants across the United States, with 1 in 5 children presenting to health care providers, and up to 3% of all infants requiring hospitalization.¹ Recent estimates report approximately

150,000 bronchiolitis hospitalizations per year.² National hospital charges related to bronchiolitis have been increasing over time, from \$1.3 billion in 2000 to \$1.7 billion in 2009.³

High-flow nasal cannula (HFNC) therapy is a relatively recent respiratory support modality that allows for higher flows of O₂ via heating and humidification of the breathing gas compared to standard O₂ therapy. HFNC has been

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utilized for patients ranging in age from preterm neonates to adults and in a variety of disease states. The use of HFNC in patients with bronchiolitis has led to a decrease in the need for intubation and in length of stay (LOS) in the hospital compared to standard O₂ therapy.⁴⁻⁸ HFNC also decreases re-intubation rates within 72 h after extubation compared to with standard O₂ therapy.⁹

Despite the adoption of HFNC as a primary respiratory modality before using noninvasive ventilation (NIV) and intubation for bronchiolitis in pediatric ICUs (PICUs), there is no standardized protocol for initiation, escalation, or weaning of HFNC.¹⁰ Respiratory therapist (RT)-driven standardized management protocols have been successfully used in PICUs, demonstrating effective and efficient care.¹¹⁻¹³ Previous studies have reported that the implementation of inter-professional quality improvement initiatives not only improved subjects' clinical outcomes and increased RT satisfaction, but also did not lead to an increase in adverse events.^{14,15}

The aim of this quality improvement project was to decrease the duration of HFNC in the PICU via a standardized RT-driven HFNC management protocol.

Methods

Setting

This quality improvement study was conducted at Riley Hospital for Children at Indiana University Health. Our PICU is a 36-bed multidisciplinary medical-surgical unit with approximately 2,500 admissions per year. HFNC by Fisher and Paykel Healthcare (Optiflow, Auckland, New Zealand) was used in our hospital and is only available in our ICUs. Subjects are not transferred to the general pediatric ward until they are weaned to standard O₂ therapy or room air. Traditionally, the HFNC initiation, escalation, and weaning decisions have been managed by the PICU clinician team (attending, fellow, resident, and advanced care providers). The study was reviewed and exempted by the Indiana University institutional review board as a quality improvement project prior to implementation.

Evaluation Failure Modes of HFNC Management in PICU

A group of pediatric intensivists, a pediatric hospitalist, PICU RTs, and information technology specialists met in

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QUICK LOOK

Current knowledge

High-flow nasal cannula (HFNC) therapy is a respiratory support modality increasingly used in pediatric patients with acute respiratory failure. HFNC allows for higher flows of O₂ via heating and humidification of the breathing gas. HFNC has been utilized for patients from preterm neonates to adults and in various disease states. The use of HFNC in patients with bronchiolitis has led to a decrease in the need for intubation and in the hospital length of stay compared to standard O₂ therapy.

What this paper contributes to our knowledge

A respiratory therapist-driven HFNC management protocol for bronchiolitis was successfully implemented in a pediatric ICU. Implementation decreased HFNC duration and length of stay in the pediatric ICU and hospital.

July 2016 to analyze the failure modes and plan the HFNC management protocol (Fig. 1).

Development of HFNC Management Protocol

Between September and October 2016, the team met to establish a protocol and to plan education, data collection, data analysis, and documentation in the electronic medical records (EMR) (Cerner Corporation, North Kansas City, Missouri). The protocol utilized the Riley Hospital Respiratory Score to objectively assess clinical status of the subjects (Table 1). The score was initially created looking at five areas: breathing frequency, retractions, mental status, dyspnea, and S_{pO₂}, which came from a review of other scoring systems.¹⁶⁻¹⁸ The protocol was developed to limit complexity, with the understanding that the protocol would be followed by a multi-professional group of health care team members with varying levels of knowledge, skills, and experience.¹⁹ The scoring tool was incorporated into our EMR before protocol implementation. After the protocol was developed, it was added to the HFNC initiation order-set within the EMR, which was completed in August 2017.

Implementation of the protocol occurred in October 2017. The HFNC management protocol is shown in detail in Table 2 and Figure 2. Briefly, when any subject admitted to the PICU required HFNC, the subject was screened to determine whether they were appropriate for the protocol (see the section on study population). If none of the exclusion criteria were met, the subject was included unless the physician specifically ordered the discontinuation of the

RT-DRIVEN HFNC PROTOCOL FOR THE PICU

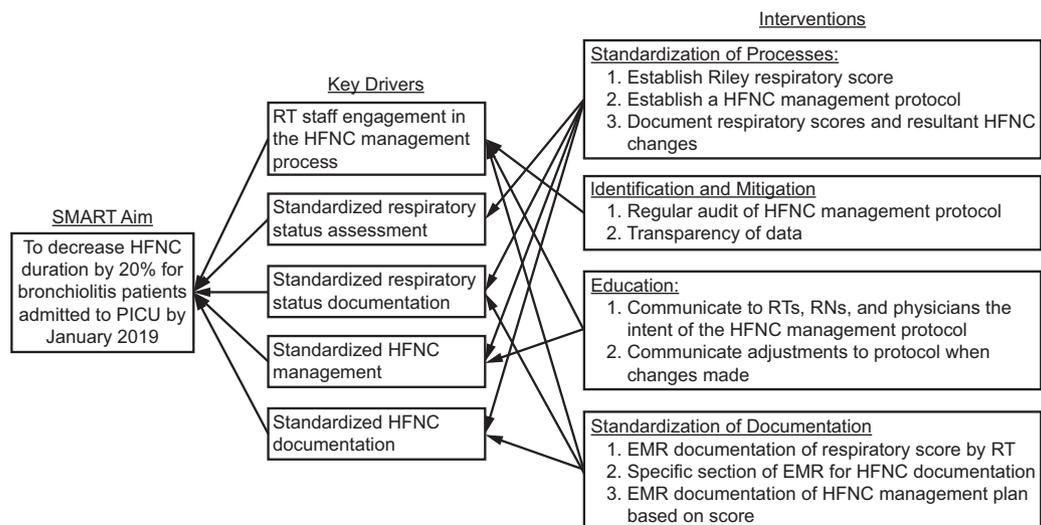


Fig. 1. Key drivers for HFNC in the PICU. PICU = pediatric ICU, EMR = electronic medical record, RN = registered nurse, HFNC = high-flow nasal cannula, RT = respiratory therapist.

Table 1. Riley Hospital Respiratory Score

	Score		
	0	1	2
Breathing frequency, breaths/min			
Age < 1 y	≤ 60	61–70	> 70
Age 1–3 y	≤ 40	41–50	> 50
Age 4–5 y	≤ 34	35–42	> 42
Age 6–12 y	≤ 30	31–38	> 38
Age ≥ 13 y	≤ 16	17–24	> 24
Work of breathing (all ages)	0–1 of the following	≥ 2 of the following	≥ 2 of the following
	Nasal flaring	Nasal flaring	Head bobbing
	Subcostal retractions	Subcostal retractions	Grunting
	Substernal retractions	Substernal retractions	Supraclavicular retractions
	Intercostal retractions	Intercostal retractions	Suprasternal retractions
			Sternal retractions

protocol. Physician reasons for discontinuation were not protocolized or monitored. The protocol was printed, laminated, and hung on every HFNC unit in our PICU.

Protocol Education

Protocol education was completed between August and October 2017. The education plan consisted of a formal presentation and a case study with a written test to demonstrate understanding of the protocol and the associated EMR documentation. The education was provided by the RT supervisor and the clinical specialists in the PICU. Questions and clarifications were provided to team members via electronic communication and daily huddles

throughout the first 2 months of implementation. Re-education of RTs occurred in May 2018. Protocol compliance audits were done twice weekly, and feedback was provided to RTs regarding protocol adherence and audit findings monthly through e-mail, face-to-face interactions, and during RT meetings and huddles.

Study Measures and Data Collection

The pre-implementation period was between October 2015 and September 2017, and the post-implementation period occurred between October 2017 and January 2019. HFNC duration was used as the primary outcome measure, while LOS in the PICU and hospital were used as secondary outcome

Table 2. Initial Settings and Escalation Guidelines for High-Flow Nasal Cannula Therapy

	Newborn	Infant	Toddler	School Age	Adolescent/Adult
Age	Up to 1 month	1–12 months	1–5 y	6–12 y	≥ 13 y
Cannula selection	Yellow	Purple	Green	Green	Clear
Initial flow, L/min	6	8	10	12	15
Soft escalation (ie, notify pediatric ICU resident)	Not applicable	Increase flow by 2 L/min every 15–30 min to 14 L/min	Increase flow by 2 L/min every 15–30 min to 20 L/min	Increase flow by 2 L/min every 15–30 min to 20 L/min	Increase flow by 5 L/min every 15–30 min to 40 L/min
Hard escalation (ie, notify pediatric ICU attending/fellow)	Increase flow by 2 L/min every 15–30 min to a maximum of 8 L/min	Above 14 L/min, increase flow by 2 L/min every 15–30 min to a maximum of 20 L/min	Above 20 L/min, increase flow by 2 L/min every 15–30 min to a maximum of 25 L/min	Above 20 L/min, increase flow by 2 L/min every 15–30 min to a maximum of 25 L/min	Above 40 L/min, increase flow by 5 L/min every 15–30 min to a maximum of 60 L/min

HFNC = high-flow nasal cannula.

measures. Protocol compliance was used as a process measure. NIV use (including CPAP and bi-level positive airway pressure), intubation rate, and 30-d PICU readmission rate were used as balancing measures. For duration of HFNC, data were extracted from EMR on a monthly basis to evaluate protocol effectiveness and to provide feedback to the team members. Protocol compliance was obtained by weekly auditing of all subjects requiring HFNC. Final analysis was conducted on data obtained from Virtual PICU Systems (VPS, Los Angeles, California). RT satisfaction was conducted pre- and post-protocol implementation via electronic surveys (SurveyMonkey, Providence, Rhode Island) that were sent to all core PICU RTs in June 2017 and January 2019, respectively.

Subject Population

The HFNC protocol was used in all patients who required HFNC in the PICU. Exclusion criteria at initiation of the protocol were subjects requiring heliox, nitric oxide, and continuous albuterol nebulization. A change was made in the protocol in April 2019 to include patients who were on continuous albuterol. For this paper, we only included subjects who were less than 24 months old and had a primary diagnosis of bronchiolitis. Patients requiring NIV or intubation were excluded from analysis of the outcome and process measures and were used only to monitor balancing measures.

Statistical Analysis

The QI Macros add-in for Excel 2018.09 (KnowWare International, Denver, Colorado) was used to generate the run charts and x-bar statistical process control charts of the outcome and process measures. To overcome the seasonal variation impacting the number of patients with bronchiolitis admitted to PICU, subjects were divided into groups of 10. The upper control limit and lower control limit were calculated as 3 σ above and below the center line. We considered 8 consecutive points above or below the center line to represent a special cause variation, and this prompted a change in the center line.²⁰ Subject demographics and clinical characteristics in the pre-HFNC and HFNC weaning protocol were compared using appropriate parametric and nonparametric tests, Wilcoxon rank-sum test for continuous variables and chi-square tests for categorical variables, with Fisher exact tests used when cell counts were small. Statistical analysis of the subjects' characteristics between the 2 groups was performed using STATA 12.1 (StataCorp, College Station, Texas). A cut-off *P* value of < .05 was considered statistically significant.

Results

During the HFNC weaning protocol pre-implementation period, 257 subjects were admitted with bronchiolitis

RT-DRIVEN HFNC PROTOCOL FOR THE PICU

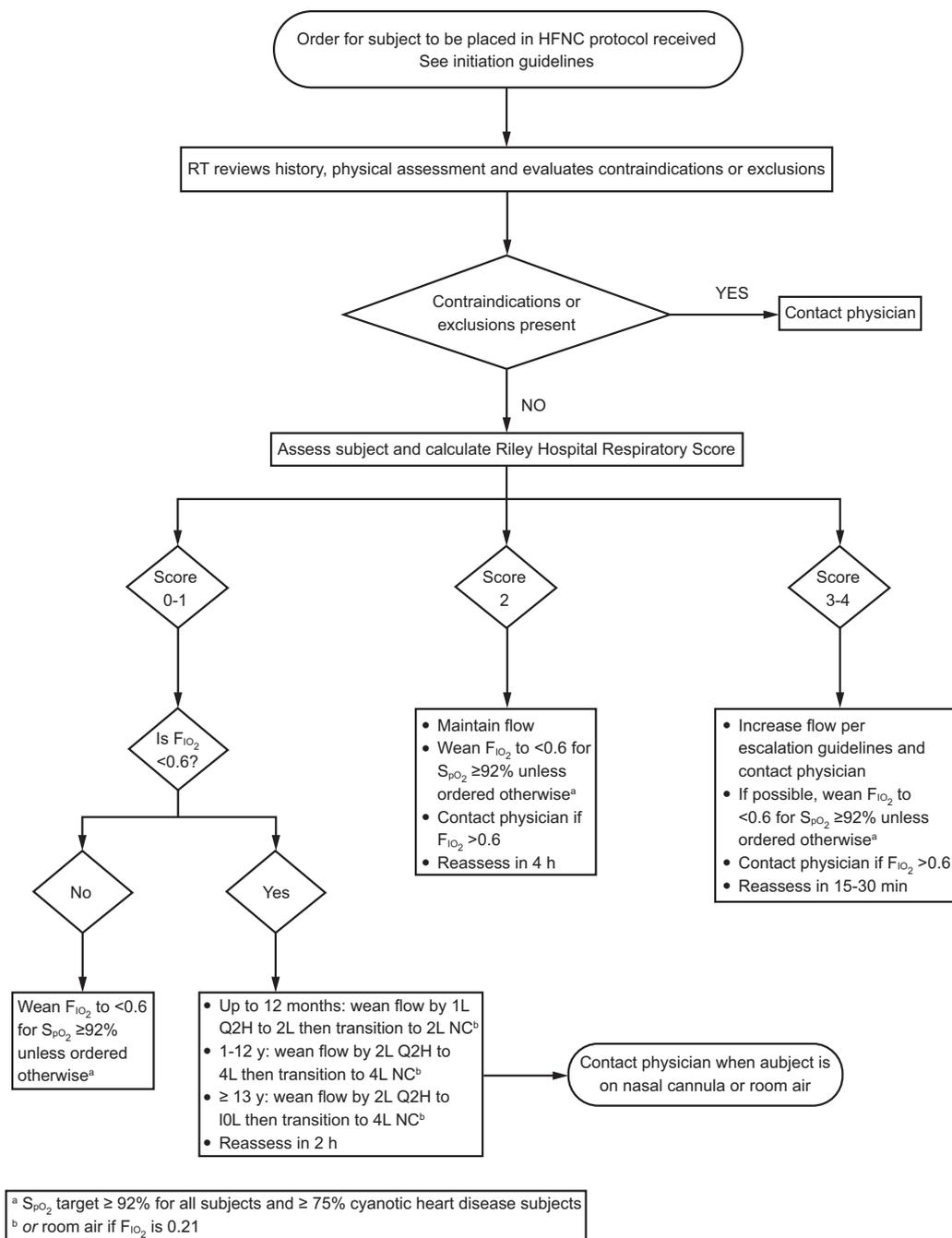


Fig. 2. Riley Hospital HFNC Management Protocol. HFNC = high-flow nasal cannula, RT = respiratory therapist.

compared to 333 subjects in the implementation period (see the supplementary materials at <http://www.rcjournal.com>). There was no significant difference in subject characteristics between the pre-protocol period and during the HFNC protocol implementation period except in female gender ($P = .02$) and race/ethnicity ($P = .037$).

Protocol compliance started with 50% and gradually improved to a median of 86%, which was above our goal of 80% (Fig. 3). For the outcome measures, the average HFNC

duration per subject dropped from 2.5 d to 2 d during the planning period for the HFNC management protocol. After protocol implementation, HFNC duration dropped further to 1.8 d (Fig. 4). The average PICU LOS showed a drop from 2.6 d to 2.1 d after protocol implementation (Fig. 4). The average hospital LOS also dropped from 5.7 d to 4.7 d after protocol implementation (Fig. 4). The use of NIV and rate of intubation did not change after protocol implementation (6.3% vs 3.7%, $P = .13$ and 17.3% vs 14.5%, $P = .13$,

RT-DRIVEN HFNC PROTOCOL FOR THE PICU

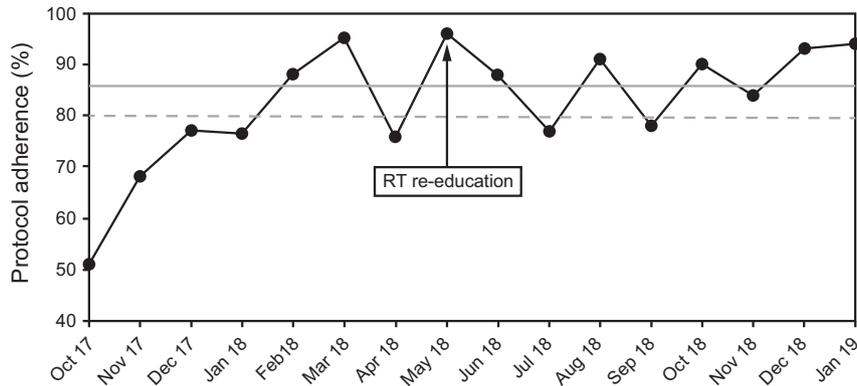


Fig. 3. Run chart for high-flow nasal cannula management protocol adherence. Horizontal line denotes median, dashed horizontal line shows goal. RT = respiratory therapist.

respectively). None of the subjects were readmitted to the PICU within 30 d in both the pre-implementation group and the HFNC group.

RTs reported an increase in their involvement in management decisions for subjects on HFNC in the PICU from 44.5% to 67.9% ($P < .001$) and improved perceived appropriateness on how quickly the team weaned HFNC from 41.7% to 63% ($P < .001$) (Fig. 5). In addition, RTs perceived they were less likely to be excluded from HFNC management decisions (62.9% to 39.3%, $P < .001$) (Fig. 5).

Discussion

To our knowledge, this is the first reported RT-driven quality improvement HFNC management protocol in the PICU setting. An RT-driven protocol can be safely implemented in the PICU and can result in decreased HFNC duration, PICU LOS, and hospital LOS without increasing PICU readmission, NIV, or intubation rates. In busy PICUs with high patient acuity, inter-professional collaboration between various team members is vital for quality and efficient care for all patients. Protocols that allow inter-professional team members to work with greater autonomy allow for improvement in both patient care and workflow.

We believe that the key components for a successful RT-driven management protocol are based on the following: (1) involving inter-professional team members in analyzing failure modes and establishing the protocol; (2) integration of the protocol in EMR, which improves the communication of protocol adherence between team members; (3) conducting education before implementation of the protocol; (4) frequent audits for protocol compliance, providing team members with feedback and re-education when needed, and (5) modifying the protocol to reach the project's goals.^{14,15}

HFNC is becoming first-line therapy in many PICUs to treat patients with bronchiolitis. Standardized clinical

pathways have consistently demonstrated cost effectiveness and improved patient outcomes,^{21,22} yet there are no standards for HFNC management of patients with bronchiolitis.¹⁰ The lack of guidelines on how to initiate, escalate, and wean this important modality can lead to variation of care, care team and family dissatisfaction, longer occupation of valuable PICU beds, and utilization of hospital resources.

We demonstrated decreases in HFNC duration, PICU LOS, and hospital LOS after implementation of this HFNC management protocol in our PICU. A decrease in the PICU and hospital LOS would decrease overall health care costs in an era when health care costs are increasing.²³ Our PICU LOS and hospital LOS were shorter than what was reported by Better et al,²⁴ despite having a younger population in our cohort, with 2.1 d and 4.7 d compared to 6 d and 10 d, respectively. The longer LOS reported by Better et al²⁴ could be explained by differences in patient population because they included subjects with multiple disease processes in comparison to the more homogenous population in our study. They also used HFNC as a step-down respiratory support modality for subjects who were intubated or required NIV. We suspect that seasonal variation, which can affect viral severity, may also have contributed to differences between our studies.

In a comparison of our protocol to the report published by Better et al regarding the implementation of their HFNC weaning protocol in the PICU,²⁴ our management protocol may be more appealing to bedside RTs and clinical team members because it is straightforward and simplified. Simplification of the protocol allows RTs with varying experience levels to implement it effectively. Our protocol also gives the RT autonomy, not only to wean HFNC, but to also select the initial flow and escalate the HFNC until achieving the respiratory score goal. Our protocol is also designed to include physicians of different training levels (ie, residents and fellows) when more escalation of care is needed. The protocol also calls for more frequent assessment to assure safety

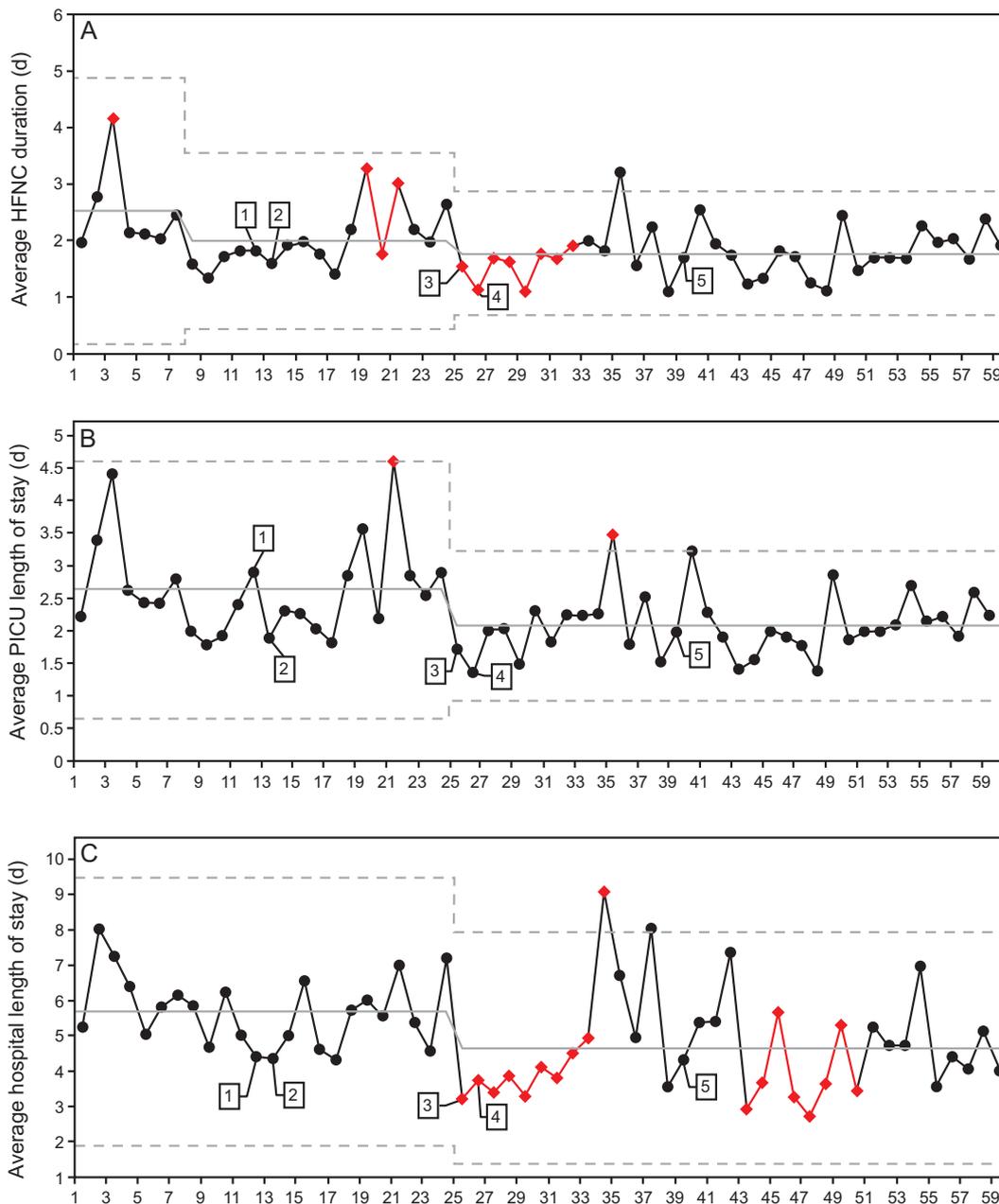


Fig. 4. X-bar control charts for average HFNC duration (A), average PICU length of stay (B), and average hospital length of stay (C). HFNC = high-flow nasal cannula, PICU = pediatric ICU. Solid lines denote center lines, dashed lines show upper and lower control limits. Red points indicate special-cause variation. Note the desired direction for each panel is downwards. 1. First team meeting to establish the protocol (July 2016); 2. Development of Riley Hospital Respiratory Score (October 2016); 3. Finish EMR protocol integration (August 2017); 4. Finish respiratory therapist education and protocol launch (October 2017); 5. Respiratory therapist re-education (May 2018).

and efficacy in escalation and gradual weaning the HFNC, which may be considered a more acceptable approach than doing HFNC holiday as reported by Better et al.²⁴

It is notable that the duration of HFNC dropped from 2.5 d to 2 d during the planning period and prior to implementation of the HFNC management protocol. This was a larger decrease than that was observed during the implementation period (ie, from 2 d to 1.8 d). This could be

due in part to informal early adoption of the HFNC protocol by RTs and physician prior to the formal implementation date, given that many of the team members were included in the establishing the protocol.

A major strength of our protocol is that it is RT-driven. This allows the RT to have independence to the fullest extent of their scope of practice. Despite this protocol adding relative value units to the work load of RTs, overall it was

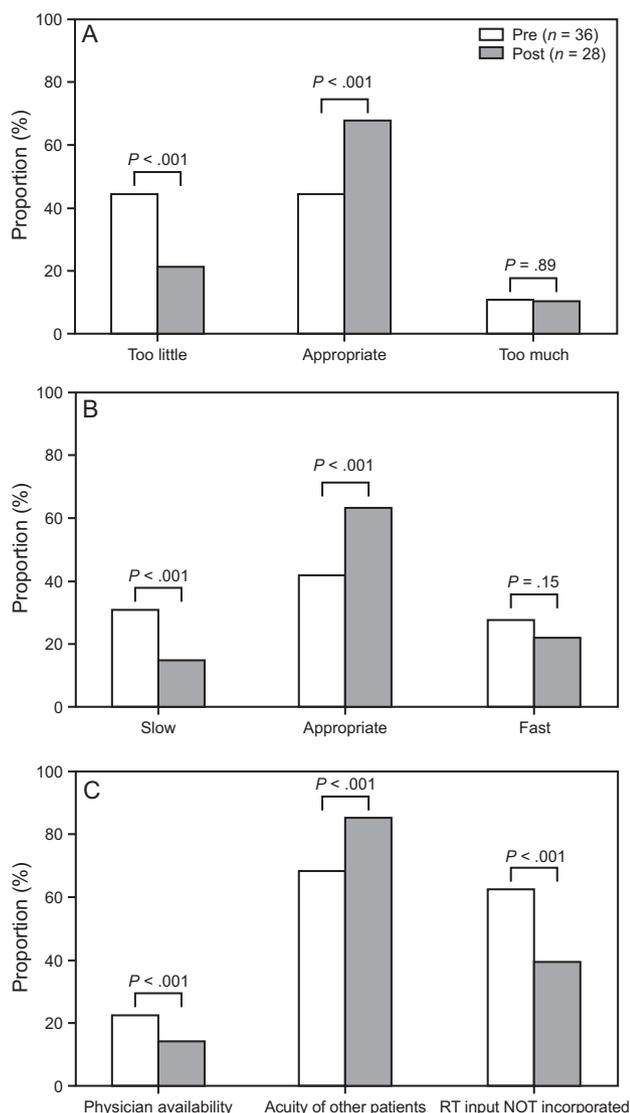


Fig. 5. A: Respiratory therapists' (RTs) opinion of their involvement in HFNC management decisions in PICU. B: RTs' opinion on how quickly the team weaned HFNC. C: RTs' perception of barriers to weaning HFNC efficiently. HFNC = high-flow nasal cannula, PICU = pediatric ICU.

looked upon favorably. RTs reported that their job satisfaction and involvement improved after protocol implementation. This is important as burnout has been linked, across job disciplines, to contribute to worse patient outcomes.²⁵ This result supports prior study reporting that respiratory care protocol use increases RTs' perceived job satisfaction.²⁶ Our protocol allows RTs to utilize their unique skill sets where best suited, which can be helpful in busy, high-acuity ICUs.

Limitations

This project utilized an initiative at a single center, limiting its generalizability to other centers. The Riley

Hospital Respiratory Score has not been validated before implementation, also potentially limiting the extrapolation of these findings. Although Shein et al¹⁹ recently reported that the retractions only score correlated with objective measure of the patient's work of breathing, the use of NIV and intubation, and was comparable to more complex scores.

It should be noted that, although the protocol compliance improved over time, for 7 of 16 months of protocol implementation the compliance rate was below our goal of 80% (Fig. 3). Four of those 7 months were near the beginning of protocol implementation, when the RT and clinical teams may have needed more time to become familiar and comfortable using the protocol. While we implemented regular education sessions for RTs, we realize that our protocol compliance reports could have been provided in a more timely manner to the RTs on our team. This could have allowed for more consistent compliance rates and might have led to larger reductions in HFNC duration.

It is possible that other extraneous factors may have influenced our PICU and hospital LOS, such as ward bed availability, ability for patients to tolerate oral intake, and family circumstances that may have prevented patients from being able to discharge home safely. Several of these extraneous factors can be difficult to monitor and were outside of the scope of this study. It is also important to consider that provider fatigue may lead to a decrease in compliance. We did not see this result, but we concluded the continued data analysis in January 2019.

While we had positive results after implementing our protocol, a multi center quality improvement collaborative project is needed to confirm the benefits of this protocol in other centers with different HFNC practices and RT/clinical teams' staffing models. The safety and efficacy of using a modified version of this protocol (with limitation of maximum flow of HFNC) outside the PICU on a hospitalist service requires further investigation. Such a modified protocol would free some of the limited PICU beds during months when viral respiratory illnesses can overwhelm PICUs.

Conclusions

A respiratory therapist-driven HFNC management protocol for bronchiolitis was successfully implemented in our PICU. The protocol can decrease HFNC duration, as well as PICU and hospital LOS. Such a protocol improves RT job satisfaction and aids in supporting RTs' involvement as vital members of the PICU team.

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