Quality Initiative to Reduce High-Flow Nasal Cannula Duration and Length of Stay in Bronchiolitis

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ABSTRACT

OBJECTIVES: High-flow nasal cannula (HFNC) use in bronchiolitis may prolong length of stay (LOS) if weaned more slowly than medically indicated. We aimed to reduce HFNC length of treatment (LOT) and inpatient LOS by 12 hours in 0- to 18-month-old patients with bronchiolitis on the pediatric hospital medicine service.

METHODS: After identifying key drivers of slow weaning, we recruited a multidisciplinary “Wean Team” to provide education and influence provider weaning practices. We then implemented a respiratory therapist–driven weaning protocol with supportive sociotechnical interventions (huddles, standardized orders, simplification of protocol) to reduce LOT and LOS and promote sustainability.

RESULTS: In total, 283 patients were included: 105 during the baseline period and 178 during the intervention period. LOT and LOS control charts revealed special cause variation at the start of the intervention period; mean LOT decreased from 48.2 to 31.2 hours and mean LOS decreased from 84.3 to 60.9 hours. LOT and LOS were less variable in the intervention period compared with the baseline period. There was no increase in PICU transfers or 72-hour return or readmission rates.

CONCLUSIONS: We reduced HFNC LOT by 17 hours and LOS by 23 hours for patients with bronchiolitis via multidisciplinary collaboration, education, and a respiratory therapist–driven weaning protocol with supportive interventions. Future steps will focus on more judicious application of HFNC in bronchiolitis.

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Dr Charvat conceptualized and designed the study, recruited the multidisciplinary workgroup, performed all chart review, maintained a secure database, created statistical process control charts, performed descriptive statistics, drafted the initial manuscript, incorporated various edits and suggestions into the final manuscript; Dr Orenstein conceptualized and designed the study and approach to statistical analysis and performed the first extensive round of edits to the manuscript by providing suggestions on how to incorporate the current literature into the discussion; Ms Miller conceptualized the study idea, helped create the weaning protocol, devised plan-do-study-act cycles, and revisied the plan-do-study-act methodology section of the manuscript; Dr Jain, integral to control chart creation and analysis, conceptualized and designed the study and reviewed and revised the manuscript, focusing on quality improvement methodology and language; Dr Edmond advised on study design and statistical analysis and revised the manuscript, focusing on clarifying plan-do-study-act cycle descriptions, defining outcomes, and offering key edits for how we presented our statistical findings; Dr Sanders conceptualized and designed the study and approach to statistical analysis, performed a 10% audit on charts reviewed by Dr Charvat, drafted the initial manuscript, was involved in all aspects of critically reviewing and revising the final manuscript, and refined submitted tables and figures; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.
Bronchiolitis is a viral lower respiratory tract infection that accounts for ~130,000 annual admissions in the United States and >18% of hospitalizations in infants <12 months of age. The 2014 American Academy of Pediatrics bronchiolitis clinical practice guideline recommends supportive management, including suctioning, maintaining hydration, and providing supplemental oxygen for hypoxemia. One form of respiratory support, high-flow nasal cannula (HFNC), has been theorized to improve work of breathing, oxygenation, and ventilation in a weight- and dose-dependent fashion. HFNC for bronchiolitis has become commonplace on the general pediatric floor both as an early intervention and as a rescue therapy.

Reported HFNC length of treatment (LOT) for bronchiolitis ranges from 43 to 72 hours, and bronchiolitis length of stay (LOS) ranges from 1 to 6 days. Wide variability is likely due to heterogeneity in reporting methods, included patient populations, definitions of bronchiolitis and HFNC, and spectrum of illness severity.

Despite the ubiquity of bronchiolitis, randomized controlled trials have neither identified which patients may benefit from HFNC nor reported improvements in clinically meaningful outcomes, including duration of oxygen therapy, PICU use, intubation rates, or hospital LOS. Just as it is unclear which patients will benefit from HFNC, there is also a paucity of literature evaluating how to safely and efficiently discontinue this form respiratory therapy. At our own institution, a respiratory therapist (RT)–driven “High Flow Holiday” protocol implemented in the PICU was able to significantly reduce median LOT and PICU LOS by rapid weaning to conventional low-flow nasal cannula. That study included patients of all ages with various diagnoses and was performed exclusively in the PICU, in which lower patient-to-RT ratios and more intensive monitoring are standard compared with the general floor. In existing non-ICU studies, including 2 randomized controlled trials, researchers contextualized by fraction of inspired oxygen (FiO2) requirement and flow rates to drive weaning but did not assess the impact of weaning practices on patient outcomes.

As HFNC use for bronchiolitis became more common in our institution’s general care area, pediatric hospital medicine (PHM) physicians suspected some patients remained on HFNC longer than necessary. Concerns were raised that the weaning process lacked standardization and was often protracted, subjecting patients to superfluous treatment and prolonging LOS. Inspired by our PICU’s High Flow Holiday, we aimed, in 1 year, to reduce HFNC LOT and inpatient LOS by 12 hours in 0- to 18-month-old patients with bronchiolitis receiving HFNC on the PHM service.

**METHODS**

**Context**

This study was conducted at a freestanding, 295-bed, quaternary care pediatric teaching hospital in the southeastern United States. An average of 1200 patients with bronchiolitis are admitted each year. An average of 1200 patients with bronchiolitis are admitted each year. ~70% of whom are treated on the general pediatric floor and the remainder in the PICU. Patients admitted to the floor are typically managed by the PHM service, and patients managed in the PICU are typically weaned off HFNC before transfer to the floor. HFNC has been permitted on the floor since 2010. The percentage of all bronchiolitis encounters with an order for HFNC increased from 9% in 2015 to 28% in 2018 (Supplemental Fig S).

Patients with bronchiolitis receiving HFNC on the general floor are assessed at least every 4 hours by a registered RT. At the time of this study, RTs managed 9 to 12 patients across multiple hospital units, sometimes more oversight. RTs use a 6-item clinical respiratory score (CRS) (Supplemental Fig 6) to assess patient condition and response to treatment of a variety of respiratory illnesses. The CRS is widely used by members of the medical team in communications regarding patient status. The score has a maximum of 12 points with designations of mild (0–2), moderate (3–6), or severe (≥7) illness.

At the time of this quality improvement (QI) project, maximum HFNC flow rates for the floor were weight based: patients weighing <3 kg requiring HFNC were monitored in the PICU; patients weighing 3 to 5 kg could be managed on the floor at a maximum of 4 L/minute; patients weighing 5 to 10 kg could receive up to 6 L/minute on the floor; and patients >10 kg could receive up to 8 L/minute. There were no other QI initiatives or institutional changes to bronchiolitis management guidelines or discharge criteria during the study period.

We identified patients using our institution’s previously developed bronchiolitis dashboard (Qlik, King of Prussia, PA) for monitoring quality-related outcomes. The dashboard includes patients aged 0 to 18 months with a primary or secondary diagnosis of bronchiolitis and excludes patients >18 months of age because of potential overlap between bronchiolitis and reactive airway disease in these older patients. Included patients had an order for HFNC. We then excluded patients through manual chart review on the basis of any of the following criteria: (1) never actually receiving HFNC; (2) hemodynamically significant cardiac disease on daily cardiac medications (eg, furosemide); (3) lung disease requiring home oxygen; (4) not receiving an HFNC wean on the general floor; and/or (5) not being on the PHM service. Exclusion criteria were applied uniformly to the baseline and intervention groups, and patients could be included more than once if they otherwise did not meet exclusion criteria.

**Planning the Interventions**

In October 2017, we began engaging stakeholders in a dialogue surrounding...
barriers to weaning HFNC. Via unstructured interviews and observations of RTs and nurses, we found that the current state of the HFNC weaning process involved RTs and physicians independently weaning patients with little direct communication between the two and nurses relaying information between team members. These early analyses identified key drivers of slow weaning (Fig 1): absence of a prescribed weaning plan, diffusion of responsibility across different providers, and difficulties in communication among physicians, nurses, and RTs. We synthesized lessons learned from stakeholder interviews and workflow analysis to inform iterative plan-do-study-act cycles.21

Interventions

Wean Team Creation
In December 2017, we recruited nursing, RT, hospital medicine, and QI advocates onto a Wean Team. Wean Team champions were recruited for their influence with respective stakeholder groups and ability to be agents of change. Beginning in January 2018, the Wean Team held regular education sessions with nurses, RTs, and physicians. Topics included identifying respiratory distress, understanding the proposed mechanism of HFNC in the management of bronchiolitis, and reviewing the literature. The Wean Team also encouraged providers to regularly discuss weaning and incorporate rapid HFNC discontinuation into their workflow and gathered feedback regarding stakeholder response to interventions.

Protocol Released
On June 1, 2018 we released an HFNC weaning protocol for the general floor, entitled High Flow Holiday, with weaning responsibilities assigned specifically to RTs. This initial protocol suggested weaning HFNC flow by 50% or transitioning to conventional low-flow nasal cannula on the basis of the patient’s current flow rate and CRS; there were no FiO2 weaning recommendations. Weaning attempts were recommended every 8 hours between 7:00 AM and 10:00 PM. Weaning was not performed overnight because of RT workflow and to avoid interruption of patient and family sleep. Within 1 hour postwean, the RT reassessed the patient and calculated a CRS. If the patient’s CRS increased by $\geq 2$, then respiratory support was returned to prewean settings. We promoted the High Flow Holiday protocol via educational sessions for RTs, nurses, residents, and attending hospitalists and used system-wide e-mails and creative signs to highlight how to find and use the protocol.

Registered Nurse and RT Huddles
After release of the High Flow Holiday, nurses and RTs reported unfamiliarity with the protocol and uncertainty regarding which patients were appropriate to wean. To address this barrier, beginning in October 2018, our nurse and RT Wean Team champions led daily huddles on each general pediatrics unit to educate staff on the High Flow Holiday, provide copies of the protocol, and review the current census to identify patients appropriate to wean.

Standardized Orders
We received feedback that interdisciplinary communication remained inadequate, and huddles were time-consuming and not always performed. Hospitalists expressed a desire to accelerate the weaning process; some RTs were uncomfortable weaning without specific orders; and nurses felt like intermediaries between RTs and physicians. To improve interdisciplinary communication, beginning in December 2018, we implemented standardized weaning orders while still encouraging RTs to initiate weans without a specific order. Physicians could either place a standing order requesting that RTs assess for weaning readiness at least every 8 hours or a stat order (accompanied by direct phone call or Health Insurance Portability and Accountability Act–compliant message to the RT) to perform a High Flow Holiday.

Revised Protocol
RTs felt the High Flow Holiday protocol was ambiguous without recommendations on FiO2, and physicians requested more frequent HFNC weaning attempts with faster transition to room air. The final intervention in February 2019 modified the protocol (Fig 2) to include guidance on FiO2, recommended transitioning to room air instead of low-flow nasal cannula, and encouraged evaluating readiness for a High Flow Holiday at least every 4 hours with each patient assessment.
Study of the Interventions
Primary outcome measures were HFNC LOT (in hours) and inpatient LOS (in hours). Our goal was to reduce the baseline HFNC LOT by 25% (12 hours) because it was a clinically meaningful and achievable target. We hypothesized that inpatient LOS would commensurately decrease with LOT.

LOT was calculated by using time of HFNC initiation and discontinuation documented in the respiratory flow sheet in the electronic medical record (EMR). If a patient received HFNC multiple times throughout admission (ie, was weaned off then restarted later), the total HFNC duration was manually calculated. Inpatient LOS was calculated by using bed history for arrival to and discharge from the inpatient unit.

Balancing measures were floor-to-PICU transfers that occurred after a wean was initiated and 72-hour same-cause returns and readmissions. Postwean PICU transfers were identified by review of bed history in the EMR. If bed history indicated a patient was transferred to the PICU, the respiratory flow sheet was examined to determine if a wean was performed within the preceding 8 hours. To identify 72-hour readmissions and returns to an urgent care or hospital, patient encounters were reviewed for visits related to bronchiolitis, including increased work of breathing, hypoxemia, and respiratory distress. We also queried an EMR sharing system to identify returns and readmissions to other local facilities. C.C. performed chart review, and R.S. audited 10% of the charts to ensure concordance.

Statistical Analysis
Descriptive statistics comparing the baseline and intervention groups were analyzed by using Pearson \( \chi^2 \) tests to assess homogeneity for age, sex, race, insurance status, and return and readmission rates. The Mann–Whitney \( U \) test was used to compare APR-DRG SOI scores, and in post hoc analysis, it was used to compare the first ED CRS score between baseline and intervention groups.

Average HFNC LOT and LOS were plotted on X-bar control charts to track outcome measures over time as well as on S control charts to assess for the degree of variability in these measures. In each chart, the variable of interest is shown on the vertical axis in hours and time on the horizontal axis. Months with \(<5\) patients were combined with preceding months to facilitate analysis. We used standard probability-based rules to identify special cause variation, including \( \geq 8 \) consecutive points above or below the centerline to prompt a centerline shift. Data management and statistical analyses were performed by using Microsoft Excel (2016). A 2-sided \( P \) value \(<.05\) was used as the threshold for statistical significance for Pearson \( \chi^2 \) and Mann–Whitney \( U \) tests.

Ethics
This QI project was not considered human subjects research and was deemed exempt from review by our institutional review board.

RESULTS
Population
A total of 283 patients were included, 105 in the baseline and 178 during the intervention period. A significantly higher percentage of patients admitted to the general floor received HFNC therapy during the intervention period compared with the baseline (baseline 25% versus intervention 29%; \( P = .012 \); Supplemental Table 2). Descriptive statistics presented in Table 1 were comparable for patient age, race, sex, and payer status between the baseline and intervention periods. Patients in the intervention period had lower (less severe) APR-DRG SOI scores (\( P = .004 \)) and comparable initial CRSs (\( P = .84 \)) with most patients in each group receiving a moderate severity score (Table 1).

High-Flow LOT
The X-bar control chart for HFNC LOT (Fig 3A) revealed special cause variation soon after the start of interventions. The primary outcome of mean LOT decreased by 17 hours, from 48.2 to 31.2 hours. The S chart (Fig 3B) revealed centerline shift with decreased SD and narrower control limits during the intervention period.

Inpatient LOS
The X-bar control chart for LOS (Fig 4A) revealed special cause variation near the start of interventions. Mean inpatient LOS decreased by 23.4 hours, from 84.3 to 60.9 hours. The S chart (Fig 4B) revealed a centerline shift with decreased SD and narrower control limits beginning in April 2018.

Balancing Measures
There were no postwean transfers to the ICU and no differences in 72-hour same-cause return (\( P = .24 \)) or readmission (\( P = .89 \)) rates between the baseline and intervention periods (Table 1).

DISCUSSION
Through implementation of a QI initiative rooted in interdisciplinary communication and collaboration, we reduced HFNC LOT by 17 hours and LOS by 23 hours. There were no postwean PICU transfers nor increases in 72-hour same-cause returns or readmissions, illustrating that our approach accelerated HFNC discontinuation and discharge without compromising patient outcomes.

We identified special cause variation for both outcomes quickly after the start of the interventions; this is likely because the Wean Team’s commitment to relationship building fostered informal, patient-centered conversations and institution-wide interest in weaning HFNC. Regular education sessions with stakeholder groups during the first intervention cultivated a shared mental model of bronchiolitis management and reinforced rapid weaning. Implementation of the High Flow Holiday weaning protocol with supportive sociotechnical interventions then standardized the weaning process to promote sustainability.

Indeed, although we saw no further change in LOT or LOS after the initial period, we sustained improvements in both outcomes for an additional 8 months after the centerline shift. We hypothesize that LOT and LOS were not further reduced because our institution’s baseline HFNC LOT was already...
We suspect improvements in LOS variation emerged later than LOT because it took time for stakeholders to become comfortable with prompt discharge after rapid discontinuation of HFNC. Although we were unable to quantify adoption of the protocol via a process measure, we did receive frequent feedback from Wean Team members reflecting broad uptake of interventions across stakeholder groups. These observations, in concert with reduced variability in outcomes, support process fidelity for weaning practices.

FIGURE 2  High Flow Holiday decision tree final protocol for 0- to 18-month-old patients with bronchiolitis on the general pediatric service. LPM, liters per minute; MD, medical doctor; RN, registered nurse.
Because HFNC use for bronchiolitis has significantly increased at our institution, patients treated with HFNC more routinely remain in general care settings. Accordingly, patients who are less ill may receive this therapy, which may partially account for lower APR-DRG SOI scores in the intervention period relative to the baseline. APR-DRG SOI calculations are dependent on the accuracy and order of diagnoses and may be impacted by differential coding strategies (eg, failing to document an underlying comorbidity) without necessarily reflecting documented clinical assessments.23–25

Despite the uncertain validity of using APR-DRG SOI scores as a proxy for clinical evaluations, we were surprised that the baseline and intervention groups differed because stakeholder gestalt was that severity was comparable. Therefore, we further evaluated patient condition by comparing initial CRS between baseline and intervention groups. By using this metric, the 2 groups were equivalent. Of note, not all patients had a documented initial CRS (88% documented in baseline versus 89% in intervention), which increases the risk of a type 2 error. We are limited in our ability to fully compare clinical severity through retrospective analysis, and lower severity of illness in the intervention group may have contributed to our observed reduction in LOT and LOS. However, equivalent initial CRS and the temporal association between interventions and outcomes suggest our QI interventions drove much of the improvement.

Our institution’s maximum flow rates at the time of this study were lower than reported in physiologic6–8 and randomized controlled studies.10–12 Suboptimal flow rates provide uncertain benefit to patients,4,6–8,26 and may have facilitated faster weaning than would be achievable with higher flow rates. Additionally, our EDs have reduced non–evidence-based therapies for severe bronchiolitis.

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**TABLE 1** Patient Characteristics, Same-Cause 72-Hour Return and Readmissions, APR-DRG SOI Score, and First CRS in the ED in the Baseline (October 2016 to November 2017) Versus Intervention (December 2017 to May 2019) Groups

<table>
<thead>
<tr>
<th>Patient Characteristics</th>
<th>Baseline (n = 105), October 2016 to November 2017, n (%)</th>
<th>Intervention (n = 178), December 2017 to May 2019, n (%)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mo</td>
<td></td>
<td></td>
<td>.16</td>
</tr>
<tr>
<td>0–2</td>
<td>24 (23)</td>
<td>59 (33)</td>
<td></td>
</tr>
<tr>
<td>3–6</td>
<td>30 (28)</td>
<td>53 (30)</td>
<td></td>
</tr>
<tr>
<td>7–12</td>
<td>26 (25)</td>
<td>28 (16)</td>
<td></td>
</tr>
<tr>
<td>13–18</td>
<td>25 (24)</td>
<td>37 (21)</td>
<td></td>
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<tr>
<td>Sex</td>
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</tr>
<tr>
<td>Male</td>
<td>72 (69)</td>
<td>111 (62)</td>
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</tr>
<tr>
<td>Female</td>
<td>33 (31)</td>
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<tr>
<td>Race</td>
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<tr>
<td>Black</td>
<td>50 (48)</td>
<td>102 (57)</td>
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</tr>
<tr>
<td>White</td>
<td>42 (40)</td>
<td>60 (34)</td>
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<tr>
<td>Asian</td>
<td>5 (4)</td>
<td>5 (3)</td>
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<tr>
<td>Other</td>
<td>8 (8)</td>
<td>11 (6)</td>
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<tr>
<td>Medicaid status</td>
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<td>Medicaid</td>
<td>77 (73)</td>
<td>125 (70)</td>
<td>.69</td>
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<tr>
<td>Commercial</td>
<td>24 (23)</td>
<td>48 (27)</td>
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<tr>
<td>Other</td>
<td>4 (4)</td>
<td>5 (3)</td>
<td></td>
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<tr>
<td>APR-DRG SOI score</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Severity 1</td>
<td>40 (38)</td>
<td>97 (55)</td>
<td>.004</td>
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<tr>
<td>Severity 2</td>
<td>41 (39)</td>
<td>63 (35)</td>
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<tr>
<td>Severity 3</td>
<td>23 (22)</td>
<td>16 (9)</td>
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<tr>
<td>Severity 4</td>
<td>1 (1)</td>
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<td></td>
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<tr>
<td>First ED CRS*</td>
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<tr>
<td>Mild (0–2)</td>
<td>32 (35)</td>
<td>47 (30)</td>
<td>.84</td>
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<tr>
<td>Moderate (3–6)</td>
<td>56 (61)</td>
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<tr>
<td>Severe (≥7)</td>
<td>4 (4)</td>
<td>3 (2)</td>
<td></td>
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<tr>
<td>Same-cause return</td>
<td>5 (4.8)</td>
<td>4 (2.2)</td>
<td>.24</td>
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<tr>
<td>Same-cause readmission</td>
<td>2 (1.9)</td>
<td>3 (1.7)</td>
<td>.89</td>
</tr>
</tbody>
</table>

* Baseline first CRS: n = 92 (88%); intervention first CRS: n = 158 (89%).
bronchiolitis (eg, albuterol), but in an effort to still do something, they may have inadvertently increased HFNC use. Thus, a limitation of our project is that some of our success lies in weaning patients who likely never needed HFNC. Given the national trend of increasing noninvasive ventilation use for bronchiolitis, this is probably true across institutions and further underscores the importance of having a standardized and rapid approach to de-escalation of respiratory support.

Overuse of bronchiolitis therapies is a well-described problem, and this study was conceived in response to concerns about avoidable resource overuse. Although not specifically directed at HFNC, researchers in other studies have demonstrated that treatment overuse impacts costs, LOS, and outcomes and can be mitigated by QI endeavors such as this one. Although this project was implemented at a quaternary care teaching hospital with unique structural and cultural challenges, the Value in Inpatient Pediatrics Network has previously demonstrated successful reduction of non–evidenced-based bronchiolitis therapies at both community and tertiary centers. Therefore, components of our project are likely adaptable to other settings, including implementation of an RT-
driven weaning protocol, supportive huddles, standardized orders, and an emphasis on interdisciplinary communication.

Given the widespread application of HFNC for bronchiolitis without evidence of a clear-cut benefit, our next steps locally will target more judicious use of HFNC via collaboration with our ED to identify HFNC initiation criteria. We also hope to partner with other institutions to validate our approach and identify additional effective strategies to reduce HFNC overuse.

Acknowledgments

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REFERENCES


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