ABSTRACT

OBJECTIVES: We aimed to reduce unnecessary use of high-flow nasal cannula (HFNC) at lower flow rates through the implementation of a standard daily trial off HFNC at a medium-sized academic center.

METHODS: We used an interprofessional quality improvement collaboration to develop and implement interventions to reduce HFNC waste in children aged 1 month to 24 months with bronchiolitis who were admitted to the inpatient ward or ICU. Key interventions included development and implementation of the Simple Cannula/Room Air Trial for Children (SCRATCH Trial), a standard trial off HFNC for eligible infants. Process measures were selected as metrics of use of the newly developed trial. The primary outcome measure was hours of treatment with ≤8 L per minute (LPM) of HFNC. Additional outcome measures included total hours of treatment with HFNC and length of stay.

RESULTS: A total of 271 patients were included in this study, 131 in the preimplementation group and 140 in the postimplementation group. The mean hours of treatment below our a priori determined waste line (≤8 LPM of HFNC) decreased from 36.3 to 16.8 hours after SCRATCH Trial implementation, and mean length of stay decreased from 4.1 to 3.0 days.

CONCLUSIONS: The SCRATCH Trial was successfully implemented across hospital units, with a significant reduction in hours on ≤8 LPM of flow. Rapid discontinuation of HFNC appears feasible and may be associated with a shorter length of stay.
Viral bronchiolitis is a leading cause of hospitalization in the first year of life, with direct medical costs increasing annually.\(^1\)\(^2\) Whereas supportive care is the mainstay of treatment, the use of heated and humidified high-flow nasal cannula (HFNC) in the treatment of bronchiolitis has increased dramatically over the last 10 years, and in part has driven increased health care costs.\(^3\) Early observational literature in the critical care setting indicated reduced rates of intubation in infants with severe bronchiolitis when HFNC therapy was provided at flow rates of 2 L/kg per minute.\(^4\)\(^5\) More recent observational literature documents the cost of early adoption from no change in outcomes including length of stay (LOS) or intubation rates, to increased PICU use with adoption of ward-based HFNC protocols.\(^6\)\(^7\) Evidence from randomized controlled trials reveals that early use of HFNC may be unnecessary because it does not reduce the need for ICU transfer, noninvasive ventilation, or the total time of oxygen therapy.\(^8\)\(^9\) Other consequences of wasteful use of HFNC include prolonged discomfort and delayed enteral nutrition.\(^10\)

At our institution, we have observed increased use of HFNC in the inpatient ward and PICU. Despite efforts to combat HFNC waste by standardizing therapy to respiratory severity scores (with HFNC indicated only for patients with “severe” scores) and acculturating HFNC weaning guidelines, HFNC use continued to increase. Of particular concern are patients who stagnate at 4 LPM of HFNC or continue to use the HFNC machine despite flows <4 LPM because of perceived fear of weaning too rapidly.

We formalized an institutional leadership structure to focus on bronchiolitis quality improvement (QI), the Bronchiolitis Improvement Group (BIG), with stakeholder representatives from nursing, respiratory therapy (RT), and physician teams in the emergency department (ED), PICU, and pediatric hospital medicine. The overall aim of the BIG is to improve the value of care provided to infants hospitalized for bronchiolitis. Our first major aim was to reduce HFNC waste, targeting patients no longer benefiting from the device and those treated at subtherapeutic flow rates, at which any potential benefit from increased end expiratory volumes would be lost.\(^11\)

Previous literature described protocols for a trial off HFNC as a safe and effective method of weaning HFNC.\(^12\) Building off this evidence, we developed our own process to trial patients off lower flows of HFNC. We modeled our work after the concept of a spontaneous breathing trial for an intubated patient already acculturated at our institution.\(^13\) We developed the Simple Cannula/Room Air Trial for Children (SCRATCH Trial), a standard daily trial off HFNC for eligible infants. The specific aim of this QI project was to reduce the hours of treatment with ≤8 L per minute (LPM) of HFNC by 25% within 1 year of trial implementation (Fig 1).

**METHODS**

**Context**

We conducted this QI project at a 150-bed tertiary care pediatric academic medical center from December 2016 to March 2020. At our institution, we care for ~150 to 200 patients with bronchiolitis per year between our PICU (20 beds) and inpatient wards (90 beds). Care teams consist of pediatric intensivists, pediatric hospitalists, pediatric residents, pediatric nurses, and pediatric respiratory therapists.

All infants admitted to the inpatient ward for bronchiolitis were cared for according to our institution’s bronchiolitis protocol. HFNC was introduced in our institution in 2011 with use approved for both the inpatient units and PICU. Alongside the improvement interventions outlined below, our bronchiolitis protocol was updated in 2018 to recommend initiation of HFNC at 1 to 2 L/kg per minute. With this change, maximum flow rates were defined for the inpatient units as 2 L/kg per minute, and, if no clinical improvement was noted after 4 hours of treatment, transfer to the PICU was recommended. No changes were made to the existing weaning protocol, and no specific QI efforts were devoted to HFNC initiation during our study period.

**Intervention**

During the spring of 2018, the BIG developed a key driver diagram to inform our work and began development of a novel rapid discontinuation tool for infants with bronchiolitis on HFNC (Fig 1). The resultant Simple Cannula/Room Air Trial for Children trial (SCRATCH; see Supplemental Information)

**Global Aim**

Reduce overuse of HFNC in healthy infants with bronchiolitis

**Smart Aim**

Reduce hours of treatment with ≤8 L HFNC by 25% within 1 year of implementation of SCRATCH Trial protocol

**Balancing Measures**

ICU transfer after SCRATCH
PPV after SCRATCH
Readmission rate

**Key Drivers**

Identification of clinical readiness for HFNC wean

Nurse and RT documentation of HFNC weaning

Physician, nursing, and RT buy-in

**Interventions**

Development of rapid HFNC discontinuation protocol (SCRATCH Trial)

Provider, RN, RT education

EMR order sets for SCRATCH Trial order

Documentation flow sheet rows for eligibility screening and trial outcome

Positive reinforcement: run charts shared

Real-time process validation

RN and RT feedback forms

**FIGURE 1** Key driver diagram for HFNC QI project. PPV, positive pressure ventilation; RN, registered nurse.
is a standardized daily trial off HFNC for eligible patients. Over the subsequent viral seasons, using plan-do-study-act (PDSA) methodology, we developed and implemented 4 interventions aimed at successful SCRATCH Trial implementation (Table 1).

**PDSA Cycle 1**
The first PDSA cycle included institutional approval of the SCRATCH Trial Protocol and development of electronic medical record (EMR) order sets. Full details of the SCRATCH Trial Protocol can be referenced in Supplemental Fig 4. Patients included in the SCRATCH trial were healthy infants between 1 and 24 months of age with a primary diagnosis of bronchiolitis receiving HFNC. Patients meeting inclusion criteria were screened daily by nurses at 0400 for SCRATCH Trial readiness. Patient readiness was defined as fraction of inspired oxygen (FiO₂) level <40% and 1 of the following age-based flow criteria: ≤4 LPM (aged 30–90 days), 6 LPM (91 days–24 months), or 8 LPM (81 days to 24 months and admitted to the PICU).

Trials commenced with RT decreasing the HFNC flow rate to 2 LPM and 100% FiO₂ (mimicking 2 L simple cannula); or, for patients >90 days of age and on ≤4 L of flow, the device was turned off. Patients were then monitored for 60 minutes for vital sign changes outside of predefined parameters. If vital signs remained stable, patients passed the SCRATCH Trial and could remain on lower respiratory settings. If vital signs deviated or there were signs of respiratory distress, the patient failed the trial and resumed their original HFNC settings.

After protocol approval, clinical informatics helped to develop an electronic order for the SCRATCH trial. The SCRATCH order defaulted the trial to occur early in the hospital day (0400) and continue daily for 3 days unless discontinued by a provider. The SCRATCH order was both stand-alone and linked to the HFNC initiation order set. Assessment tools were created within standard respiratory therapy workflows to allow documentation of trial readiness and outcomes; this documentation also allowed RT to bill for their time and plan staffing accordingly.

**Provider Education**
In the fall of 2018, the BIG leadership team rolled out education to pediatric and family medicine residents in the form of lectures and to nursing and RT members via online modules and posted signage at clinical workstations and unit (I) boards. Monthly e-mail reminders were sent to team members during the respiratory viral season with detailed information on the SCRATCH Trial and patient eligibility.

**Process Monitoring**
Between December of 2018 and May of 2019, stakeholders performed audits of the EMR 3 times a week to identify current inpatients eligible for a SCRATCH Trial and monitor process measures in near–real time. Stakeholders followed-up with ordering providers, nurses, and RTs to discuss the new process and answer questions. During this time period, run charts and nurse and RT feedback forms were reviewed at monthly BIG meetings. Over the course of the viral season, 2 subsequent PDSAs were developed as a result of this feedback.

**PDSA Cycle 2**
It was noted that after a successful SCRATCH Trial, patients were often left on 2 L HFNC at 100% FiO₂ (via the blender), rather than transitioning over to wall oxygen and a simple nasal cannula interface. Although this practice was not proscribed by the trial protocol, it left many blenders in use. In February of 2019, RT leadership provided staff education on the use of a wall adapter that would allow the HFNC cannula and tubing to be connected directly to wall oxygen. This allowed for more formal discontinuation or removal of high-flow machines and transition of patients to wall oxygen without disturbing a sleeping infant by changing cannulae.

**PDSA Cycle 3**
During monthly review of our run charts, it was noted that the SCRATCH Trial was often ordered with HFNC on admission, but if patients did not achieve readiness for a trial within the initial 3 days, the order would be automatically discontinued, and no trial occurred. Thus, in March 2019, the SCRATCH Trial order was changed to last 5 days and increased in frequency from once to twice a day at 0400 and 1600.

**PDSA Cycle 4**
At the beginning of the second viral season after SCRATCH implementation (December 2019 to April 2020), teams were provided with laminated job aids and compendium educational references. Consolidated flowsheets with information on bronchiolitis, HFNC, and SCRATCH protocols were developed, laminated, and hung in patient rooms for easy access and to serve as a visual cue. During this second season, active monitoring of admitted patients eligible for SCRATCH did not occur. Rather, twice monthly reports from our institution's data team were generated to identify all patients <24 months of age with the diagnosis of bronchiolitis. These charts

<table>
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<th>TABLE 1 Summary of PDSA Cycles</th>
<th>Process Change</th>
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<tr>
<td><strong>PDSA Cycle</strong></td>
<td>Date</td>
</tr>
<tr>
<td>Baseline</td>
<td>December 2016 to April 2017 and December 2017 to April 2018</td>
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<tr>
<td>Cycle 1</td>
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<td>Cycle 2</td>
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were reviewed for outcome measure tracking.

**Study of the Intervention**

Retrospective cohort data (pre-SCRATCH) were collected via chart review for the 2 previous bronchiolitis seasons (December 1, 2016, to April 1, 2017, and December 1, 2017, to April 1, 2018). Included were infants 1 to 24 months of age admitted with a primary diagnosis of viral bronchiolitis and an order placed for HFNC. Patients were excluded for prematurity (<34 weeks’ gestational age), active cardiopulmonary disease, confirmed or suspected genetic syndromes, and neuromuscular disease.

Intervention cohort records (post-SCRATCH) were similarly included and reviewed in a more robust fashion compared to real-time practice monitoring. Microsoft Excel was used for process data tracking, and a Research Electronic Data Capture database was built for collection of outcome data. LOS and demographic data were pulled directly from the EMR.

Demographic data are presented and grouped by pre- and postimplementation groups, relative to a start date of December 1, 2018 (Table 2). Descriptive statistics were used to assess differences in group characteristics. SPSS version 25 (IBM SPSS Statistics, IBM Corporation) was used for analyses.

### Measures and Analysis

The primary outcome measures were the cumulative hours of HFNC support at ≤3 cutoff rates: 8 LPM, 6 LPM, or 4 LPM. Process measures included appropriate use of the SCRATCH Trial order, trial occurrence, and trial outcome. Balancing measures included PICU transfer after SCRATCH trial, need for positive pressure ventilation after SCRATCH trial, and readmission rate. We compared measures after the implementation of the SCRATCH trial (December 1, 2018, to April 1, 2019, and December 1, 2019, to April 1, 2020) with the same measures during the baseline period, defined as the 2 previous viral seasons (December 1, 2016, to April 1, 2017, and December 1, 2017, to April 1, 2018).

Process measures were plotted over time in run charts. Outcome measures were monitored by statistical process control (SPC) X-bar and S charts. Run charts and SPC charts were developed with Microsoft QIMacros.

### Ethical Considerations

Our university’s institutional review board waivered oversight of this QI initiative. Workgroup members did not interfere with clinical decisions in real time. No interventions involved comparison of therapies, and subjects were not randomly assigned. All charts were accessed by a subset of members of the improvement team, and no personal health information was shared outside of the organization.

### RESULTS

A total of 271 patient charts were reviewed, 131 in the pre-SCRATCH implementation group, and 140 in the post-SCRATCH implementation group. The characteristics of patients in the different time periods are presented in Table 2. Of the study patients admitted during the postimplementation period, a smaller percent was admitted to the PICU, with no significant difference in the percent of patients transferred from the inpatient ward to the PICU. Additionally, patients in the postimplementation time period were heavier, averaged higher maximum flow rate in L/kg per minute, and had shorter LOS.

Run charts reflecting process measures tracked during the implementation season are presented in Supplemental Fig 5. We found that 90% of eligible patients had a SCRATCH Trial order placed. Of those patients who had an order for a SCRATCH Trial placed, 83.8% of patients had at least 1 trial attempted. Overall, 82% of SCRATCH trials had an outcome of “pass.” The process measure of SCRATCH Trial order was tracked over the subsequent viral season (December 2019–March 2020) and revealed continued use of the SCRATCH Trial
with a sustained mean of 90% of eligible patients having the order placed (Supplemental Fig 6).

The mean hours of treatment with ≤4 LPM HFNC decreased from 19.5 hours to 5.8 hours after SCRATCH Trial implementation, with special cause variation (8 consecutive points below the center line) first identified on February 10, 2019. The mean hours of treatment with ≤6 LPM HFNC decreased from 31.4 hours to 12.1 hours after SCRATCH implementation, with special cause variation first identified on February 24, 2019. The mean hours of treatment with ≤8 LPM of HFNC decreased from 36.3 to 16.8 hours after SCRATCH Trial implementation, with special cause variation first identified on March 3, 2019 (Fig 2). Mean LOS decreased from 4.1 to 3.0 days, with special cause variation first identified on January 19, 2020 (Fig 3). There was no significant reduction in the total hours of treatment with HFNC after SCRATCH after SCRATCH Trial implementation (Fig 3). There were no inpatient ward-to-PICU transfers after a SCRATCH Trial, no patients started on noninvasive positive pressure ventilation after a SCRATCH Trial, and there was no change in the 7-day or 30-day readmission rates between the 2 groups.

**DISCUSSION**

Within 1 year of implementation of our interventions, the hours of treatment with ≤8 LPM of HFNC was reduced by 54%, achieving our specific aim. We found similar reductions in the hours of treatment with less than or equal to both 6 LPM and 4 LPM. In addition to establishing eligibility criteria on the basis of patient age, HFNC flow rate, and FIO2, we also clearly defined failure criteria allowing for objective assessment of patients’ tolerance of the SCRATCH Trial and outcome.

Our initial intervention of the order sets and education of relevant team members contributed to providers gaining comfort with the rapid HFNC discontinuation process. We were able to show that, on average, >80% of patients passed their SCRATCH Trial and remained on lower
FIGURE 3  A, X-bar chart reflecting mean total hours of HFNC treatment, grouped by admission week. B, S chart of the SD of each sample over time. C, X-bar chart reflecting mean LOS in days, grouped by admission week. D, S chart. UCL, upper control limit.
respiratory support. RT leadership played a key role in distributing education and run chart data to their teams and seeking feedback. Having the interprofessional and collaborative BIG provided a forum in which real-time improvements could be efficiently enacted. Engagement and input from RT and nurses were essential to the sequential change we observed.15

Our implementation of a standardized rapid discontinuation process for HFNC builds on previously described efforts.12 We did not find a significant change in the mean total hours of HFNC, despite a reduction in the number of hours patients spent on <8 LPM. We suspect this may be due in part to the concurrent, but mutually exclusive, change in HFNC initiation rates to 1 to 2 L/kg per minute, called for by bronchiolitis protocol updates. Indeed, we observed that maximum flow rates in the postintervention group were significantly higher. Given that the mean hours of treatment <4, <6, and <8 LPM were reduced without impacting the total hours of treatment, it is probable that patients spent a larger proportion of their time on HFNC at higher flow rates.

We found an overall reduction in mean LOS from 4.1 to 3.0 days greater than 1 year after SCRATCH implementation (Fig 3). This change did not occur during the protocol implementation phase. This was an unexpected finding in the setting of static total hours on HFNC. Given that the collective severity of illness of patients with bronchiolitis is likely steady year to year, it is possible that the postimplementation subjects spent a larger proportion of their entire hospital course on HFNC but were able to rapidly discontinue the therapy and discharge faster because of this new protocol. One hypothesis for this reduction in LOS is that, by defining an upper limit of flow rates for our inpatient units at 2 L/kg per minute, we were able to admit patients on HFNC to the inpatient ward at flow rates that would have previously caused them to be sent to the PICU. Although no QI efforts were put toward enforcing this updated recommendation, the maximum flow rates in the postintervention group were significantly higher. It may be that simply avoiding ICU admission contributed to our reduced LOS. Additionally, during this time period, we did not see any significant change in the percent of patients with bronchiolitis on HFNC transferred from the inpatient ward to the PICU.

This project is limited in generalizability because it is a single-center study conducted during a QI intervention. The concurrent implementation of the SCRATCH Trial and updates to our bronchiolitis protocol in relation to weight-based HFNC initiation and maximum inpatient ward flow rates limited our ability to attribute secondary outcomes to our QI intervention. Fewer patients in the intervention period were admitted to the PICU, which deserves further attention. We originally conceived of PICU transfers as a balancing measure related to safety; however, as others have pointed out, it may be appropriate to consider this a secondary outcome.7 The process for identifying eligible patients via EMR report was the same across time periods, and further data collection for subsequent seasons may yield insight into whether our observed institutional trends continue or appear to be related to seasonal variation.

CONCLUSIONS

Through this QI intervention, we were able to demonstrate the feasibility and safety of implementation of a rapid discontinuation process of HFNC for healthy infants with bronchiolitis. This trial could be implemented at other institutions with similar resources. After the implementation of the SCRATCH Trial, we were able to significantly reduce the number of hours patients were treated with <8 LPM of HFNC. Our results suggest that a rapid HFNC discontinuation tool may contribute to a reduction in LOS, and further studies are warranted. Given the high pass rate (82%) for the SCRATCH Trial identified during our 2018 to 2019 intervention season, future directions for this work include determining safety of rapid weaning or discontinuation of HFNC at potentially higher or weight-based flow rates.

Acknowledgments

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REFERENCES


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SCRATCH Trial: An Initiative to Reduce Excess Use of High-Flow Nasal Cannula
Michelle Noelck, Alex Foster, Serena Kelly, Ashley Arehart, Christina Rufener, Tamara Wagner, Laura Ibsen and Erin Burns
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