

BRIEF REPORT

Implementation of a Weight-Based High-Flow Nasal Cannula Protocol for Children With Bronchiolitis

Robert J. Willer, DO,^a Michael D. Johnson, MD, MS,^a Frank A. Cipriano, MD,^a Bryan L. Stone, MD, MS,^a Flory L. Nkoy, MD, MS, MPH,^a David C. Chaulk, MD, MPH,^a Miguel L. Knochel, MD,^a Cynthia K. Kawai, MS, APRN,^b Kristi L. Neiswender, RN,^b Eric R. Coon, MD, MS^a

ABSTRACT

OBJECTIVES: To determine if the implementation of a weight-based high-flow nasal cannula (HFNC) protocol for infants with bronchiolitis was associated with improved outcomes, including decreased ICU use.

METHODS: We implemented a weight-based HFNC protocol across a tertiary care children's hospital and 2 community hospitals that admit pediatric patients on HFNC. We included all patients who were <2 years old and had a discharge diagnosis of bronchiolitis or viral pneumonia during the preimplementation (November 2013 to April 2018) and postimplementation (November 2018 to April 2020) respiratory seasons. Data were analyzed by using an interrupted time series approach. The primary outcome measure was the proportion of patients treated in the ICU. Patients with a complex chronic condition were excluded.

RESULTS: Implementation of the weight-based HFNC protocol was associated with an immediate absolute decrease in ICU use of 4.0%. We also observed a 6.2% per year decrease in the slope of ICU admissions pre- versus postintervention. This was associated with an immediate reduction in median cost per bronchiolitis encounter of \$661, a 2.3% immediate absolute reduction in the proportion of patients who received noninvasive ventilation, and a 3.4% immediate absolute reduction in the proportion of patients who received HFNC.

CONCLUSIONS: A multicenter, weight-based HFNC protocol was associated with decreased ICU use and noninvasive ventilation use. In hospitals where HFNC is used in non-ICU units, weight-based approaches may lead to improved resource use.

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Address correspondence to Robert J. Willer, DO, Division of Pediatric Hospital Medicine, Department of Pediatrics, University of Utah School of Medicine, Primary Children's Hospital, 100 North Mario Capecchi Dr, Salt Lake City, UT 84113. E-mail: Robert.Willer@hsc.utah.edu

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Drs Willer and Coon implemented the protocol, conceptualized and designed the study, conducted data analysis and interpreted data, and reviewed and revised the manuscript; Drs Johnson, Cipriano, Nkoy, Stone, Knochel, and Chaulk implemented the protocol, conceptualized and designed the study, interpreted data, and reviewed and revised the manuscript; Ms Kawai and Neiswender implemented the protocol, conceptualized the study, interpreted data, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

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^aSchool of Medicine, University of Utah and Primary Children's Hospital, Salt Lake City, Utah; and ^bPrimary Children's Hospital, Salt Lake City, Utah

Bronchiolitis is one of the most common pediatric inpatient diagnoses, accounting for >100 000 inpatient admissions per year.¹ The use of high-flow nasal cannula (HFNC) has become popular in hospitalized children with bronchiolitis.² Initial ward-based HFNC protocols employed age-based flow rates (8–10 L/minute).^{3,4} However, literature suggests that weight-based flow rates of 2 L/kg per minute may provide greater improvement in work of breathing.^{5,6} At our institution, the first ward-based HFNC protocol was introduced in 2013 and used age-based flow rates. However, our local multidisciplinary respiratory leadership team noted that our ward-based HFNC protocol was associated with increasing noninvasive ventilation (NIV) and ICU use. In an effort to mitigate these trends, we implemented a weight-based HFNC protocol with the specific aim of decreasing ICU use.

METHODS

Patient Inclusion

We implemented a weight-based HFNC protocol on non-ICU wards at a children's hospital and 2 community hospitals. We included patients <2 years old with a discharge diagnosis of bronchiolitis or viral pneumonia during the preimplementation (November 2013 to April 2018) and postimplementation (November 2018 to April 2020) respiratory seasons. Patients with a complex chronic condition were excluded.⁷ Patients were identified if they had an *International Classification of Diseases, Tenth Revision* discharge diagnosis code consistent with bronchiolitis or viral pneumonia in any position. For patients discharged after October 1, 2015, a crosswalk was used to convert *International Classification of Diseases, Tenth Revision* codes to *International Classification of Diseases, Ninth Revision* codes.⁸

Hospital Characteristics

The children's hospital and 1 of the community hospitals include an on-site ICU. The nurses at all 3 hospitals and the respiratory therapists (RTs) at the children's hospital specialize in pediatric care.

The Intervention

A multidisciplinary team that included physicians, RTs, nurses, residents, care managers, and a medical librarian led development of the new ward-based HFNC protocol, which replaced age-based flow rates (maximum 10 L/minute) with weight-based flow rates. The new protocol made 2 principal changes in defining the targeted flow rates: (1) prescribing a standard flow rate of 2 L/kg per minute and (2) setting a maximum flow rate of 20 L/minute, for patients weighing >10 kg. Implementation strategies were consistent across all participating hospitals and included updated electronic order sets, note templates, and comprehensive education. In addition to informational presentations and e-mail correspondence, education to clinical care teams included computer-training modules, which took participants step-by-step through the new protocol with sample cases. Paper materials were distributed and large posters were displayed to ensure easy access to the new protocol.

Process Measures

Adherence to the intervention was tracked monthly by measuring "targeted" weight-based flow rates in the electronic medical record and defined as 1.75–2.25 L/kg per minute (to allow for rounding) or 20 L/minute of flow.

Outcomes

The primary outcome was "ICU use," which included any admission to the ICU (from the emergency department, the ward, or a referring hospital). Secondary outcomes included mean hospital length of stay (LOS), median cost per encounter, invasive mechanical ventilation (IMV), NIV (continuous positive airway pressure or bilevel positive airway pressure) and HFNC rates. Hospital cost was adjusted for inflation. The receipt of IMV, NIV, and HFNC was extracted from the medical record by using RT and nursing charting. Population estimates from the State Department of Health were used to calculate annual admission rates per 1000 children aged 0 to 24 months who resided in our state

each year of the study period. These rates were evaluated to determine if rates of admission were comparable before and after implementation of our protocol.⁹

Analysis

Patient characteristics were compared by using χ^2 test for categorical variables and Wilcoxon rank test for continuous variables. We used an interrupted time series approach to compare outcomes across the preintervention and postintervention seasons. We measured both the immediate change in outcomes and any change in the trend of those outcomes.¹⁰ Interrupted time series estimates were adjusted for patient age, sex, race, ethnicity, and insurance status. Linear regression was used for mean continuous outcomes and quantile regression was used for median continuous outcomes. Logistic regression was used for categorical outcomes. An ordinary least squares time series model was used to adjust for autocorrelation with Newey-West standard errors.¹¹ Analyses were performed by using Stata version 15 (Stata Corp, College Station, TX).

RESULTS

Patient Characteristics

There were 5652 bronchiolitis encounters in the pre- and 2140 bronchiolitis encounters in the postintervention periods. Small pre- versus postintervention differences were noted for patient demographics, including age (median age 6 months pre- versus 7 months postintervention, $P < .001$), weight (mean weight 7.9 kg pre- versus 8.0 kg postintervention, $P = .03$), race (multiracial mean 19% pre- versus 27% postintervention, $P < .001$), ethnicity (Hispanic mean 24% pre- versus 31% postintervention mean, $P < .001$), and insurance (government insurance or self-pay mean 46% pre- versus 41% postintervention, $P < .001$). Sex did not differ significantly between the pre- and postintervention seasons (57% male in each period).

Process Measures

In the preintervention season, the proportion of patients who received targeted flow rates was 13% compared with 86% in the postintervention seasons (Fig 1). The proportion of patients (pre-versus postintervention) who received targeted flow rates increased in a similar manner across all 3 hospitals: children's hospital (12% vs 86%), community hospital 1 (11% vs 85%), and community hospital 2 (22% vs 93%).

Primary Outcome

Implementation of the weight-based HFNC protocol was associated with an immediate absolute change in ICU use of -4.0% (95% confidence interval [CI]: -5.1 to -2.9). We also observed a change in the slope of ICU admissions pre- versus postintervention of -6.2% (95% CI: -6.7 to -5.8 ; Fig 2) per year.

Secondary Outcomes

Our weight-based HFNC protocol was associated with an immediate reduction in median cost per bronchiolitis encounter (immediate absolute change $-\$661$, 95% CI: -1006 to -316 dollars), the proportion of patients who received NIV (immediate absolute change -2.3% , 95% CI: -3.0 to -1.6), and the proportion of patients who received HFNC (immediate absolute change -3.4% , 95% CI: -5.1 to -1.8 ; Table 1). Statistically significant immediate changes were not observed for mean hospital LOS or the proportion of patients who received IMV. However, a statistically significant change in the postintervention slope was measured for all of the secondary outcomes, with the exception of cost (Table 1).

There was no difference in population-adjusted hospitalizations in the preintervention period compared with the postintervention period (immediate absolute change 0.7 bronchiolitis admissions per 1000 children, 95% CI: -4.5 to 6.0).

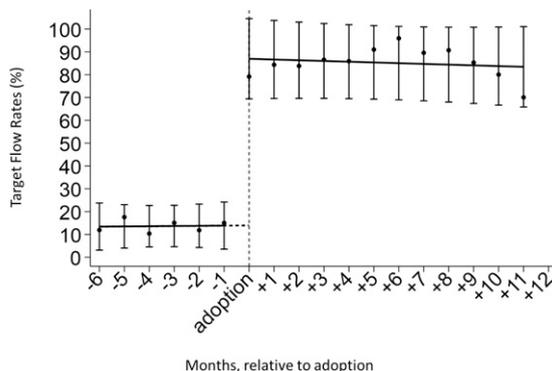


FIGURE 1 The proportion of patients who received appropriately targeted flow rates before and after adoption of a weight-based HFNC protocol. Interrupted time series analysis, displaying trends in the pre- and postimplementation respiratory seasons. Error bars represent the 95% CI. Month -1 to -6 represent the preimplementation season, whereas months $+1$ to $+6$ and months $+7$ to $+12$ represent the first and second postimplementation seasons, respectively. Because of a change in electronic medical record systems, HFNC flow rates were not available before the first preimplementation respiratory season.

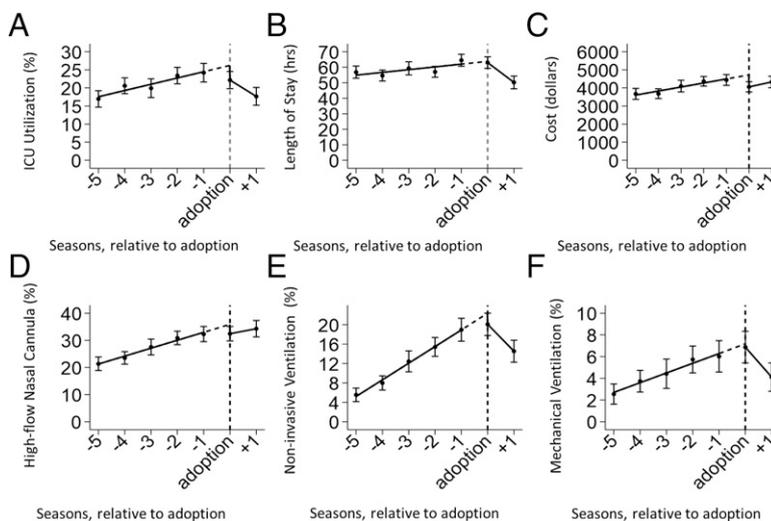


FIGURE 2 Outcomes before and after adoption of a weight-based HFNC protocol. Interrupted time series analysis, displaying trends in the pre- and postimplementation respiratory seasons. The adoption season is denoted by the vertical dotted line. There are 6 subfigures displaying the following outcomes among hospitalized children with bronchiolitis: (A) the proportion of patients admitted to the ICU, (B) total mean hospital LOS in hours, (C) median hospital cost per encounter in inflation-adjusted dollars, (D) the proportion of patients treated with HFNC, (E) the proportion of patients treated with NIV, and (F) the proportion of patients treated with IMV. Error bars represent the 95% CI.

DISCUSSION

Implementation of a weight-based HFNC protocol was associated with decreased ICU use and use of NIV. Although ward-based HFNC protocols are often implemented to reduce ICU use, recent observational studies have revealed either no improvement or a paradoxical increase in ICU use following

implementation of such protocols.^{4,12,13}

However, data from these studies were obtained when most institutions used age-based and modest (8–10 L/minute) flow rates.^{3,4} Our findings suggest that weight-based HFNC flow rates may be an important component of ward-based HFNC bronchiolitis protocols that seek to reduce ICU use.

TABLE 1 Interrupted time series analysis comparing outcomes 5 seasons before and 2 seasons after adoption of a weight-based HFNC protocol

Outcome	Immediate Absolute Change (95% CI)	Change in Slope (95% CI)
ICU use, %	−4.0 (−5.1 to −2.9)*	−6.2 (−6.7 to −5.8)*
Mean hospital LOS, hr	−0.8 (−10.1 to 8.5)	−14.5 (−17.2 to −11.9)*
Median cost per encounter, \$	−661.1 (−1006.0 to −316.2)*	−48.9 (−68.9 to 166.6)
HFNC, %	−3.4 (−5.1 to −1.8)*	−1.1 (−1.5 to −0.6)*
NIV, %	−2.3 (−3.0 to −1.6)*	−9.0 (−9.3 to −8.7)*
IMV, %	−0.3 (−1.3 to 0.7)	−3.7 (−3.9 to −3.4)*

* $P < .05$.

Our finding of decreased ICU use could be due to several reasons. It is possible that higher HFNC flow rates led to improved work of breathing, such that a portion of patients no longer needed ICU transfer.^{5,14} Alternatively, the allowance of a higher flow rate, in and of itself, could have removed the perception that ICU transfer was necessary in some cases. Finally, it is possible that children had decreased illness severity or complexity in the postintervention seasons compared with the preintervention seasons. This seems less likely for 2 reasons. First, we excluded patients with complex chronic conditions. Second, population-adjusted hospitalizations did not change significantly in the postintervention period compared with the preintervention period, arguing against the possibility that our health care system lowered the threshold for hospital admission and increased the proportion of children with lower illness severity.

Our weight-based HFNC protocol appears to have been rapidly and consistently adopted across 3 hospitals. We posit that competency, organization, and leadership drivers promoted successful implementation.¹⁵ From a competency standpoint, we ensured that providers had adequate training in the protocol by providing robust education using multiple outlets. We were transparent with front-line caregivers about the rationale for change and how we felt we could improve care. We discussed up front how our project could fail to mitigate barriers to implementation. In regard to organizational and leadership drivers, we had buy-in from the upper levels of hospital administration who supported

monthly multidisciplinary stakeholder meetings, initially to develop the protocol and then to monitor our process change.

There are limitations to our study. Although this was a multicenter study involving a children's hospital and community hospitals, the participating hospitals were part of the same health care delivery system, and findings may not generalize to other health care systems. We adjusted for measured demographic changes over the course of the study, but there may be other important unmeasured contextual and confounding factors that influenced the observed findings. Additionally, we did not measure safety events related to HFNC (ie, pneumothoraces), because they are not reliably captured in administrative data.

CONCLUSIONS

A multicenter, weight-based HFNC protocol was associated with decreased ICU use and NIV use. In hospitals where HFNC is used in non-ICU units, weight-based approaches may lead to improved resource use.

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