RESEARCH ARTICLE

Nutrition and High-Flow Nasal Cannula Respiratory Support in Children With Bronchiolitis

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ABSTRACT

OBJECTIVES: No guidelines are available regarding initiation of enteral nutrition in children with bronchiolitis on high-flow nasal cannula (HFNC) support. We hypothesized that the incidence of feeding-related adverse events (AEs) would not be associated with HFNC support.

METHODS: This retrospective study included children ≤24 months old with bronchiolitis receiving HFNC in a PICU from September 2013 through April 2014. Data included demographics, respiratory support during feeding, and feeding-related AEs. Feeding-related AEs were extracted from nursing documentation and defined as respiratory distress or emesis. Feed route and maximum HFNC delivery were recorded in 8-hour shifts (6 AM–2 PM, 2 PM–10 PM, and 10 PM–6 AM).

RESULTS: 70 children were included, with a median age of 5 (interquartile range [IQR] 2–10) months. HFNC delivery at feed initiation varied widely, and AEs related to feeding occurred rarely. Children were fed in 501 of 794 (63%) of nursing shifts, with AEs documented in only 29 of 501 (5.8%) of those shifts. The incidence of AEs at varying levels of respiratory support did not differ (P = .092). Children in the "early feeding" (fed within first 2 shifts) group (n = 22) had a shorter PICU length of stay (2.2 days [IQR 1.4–3.9] vs 3.2 [IQR 2.5–5.3], P = .006) and shorter duration of HFNC use (26.0 hours [IQR 15.8–57.0] vs 53.5 [IQR 37.0–84.8], P = .002), compared with children in the "late feeding" group (n = 48).

CONCLUSIONS: In this small, single-institution patient cohort, feeding-related AEs were rare and not related to the delivered level of respiratory support.

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More than 100 000 children are hospitalized each year with bronchiolitis, accounting for an estimated 16% of all hospitalizations among children <2 years old.[1] The American Academy of Pediatrics recommends providing appropriate fluid and nutritional support in children with bronchiolitis.[2] Bronchiolitis patients with severe dyspnea may be kept nil per os (NPO) because enteral nutrition theoretically poses the risk of aspiration and subsequent respiratory deterioration.[3,4] There are limited published data regarding appropriate nutritional support in children hospitalized with bronchiolitis, including patients with severe dyspnea admitted to the PICU.[5–9]

There are no published data regarding the safety of beginning enteral feeds in children on high-flow nasal cannula (HFNC), a respiratory support modality used with increasing frequency.[10–14] Children treated with HFNC do not consistently receive early enteral nutrition, probably because of concerns about loss of feeding coordination, aspiration risk, and impending respiratory failure, leading to invasive mechanical ventilation (MV).[3,4] These risks prompt some providers to withhold enteral nutrition until the need for HFNC abates, which is often ≤4 days.[11] However, optimal nutritional support is important in critically ill children, and enteral nutrition is generally the preferred method.[15] The purpose of this study was to describe the rates of adverse events (AEs) related to feeding in children with bronchiolitis during HFNC therapy in 1 tertiary academic PICU. We hypothesized that the occurrence of an AE related to enteral feeding would not be associated with the respiratory support the patient was receiving at the time of the feed. Additionally, we sought to investigate the associations between enteral feeding patterns and clinical outcomes, including length of stay and duration of oxygen therapy.

METHODS

Study Design and Participants

This was a retrospective chart review of children ≤24 months old admitted to the ICU of a single tertiary academic children's hospital with a primary diagnosis of bronchiolitis from September 1, 2013 to April 30, 2014. Rainbow Babies & Children's Hospital is a tertiary academic children's hospital located in Cleveland, Ohio. The PICU is a 20-bed mixed medical–surgical unit, with ∼150 bronchiolitis admissions each year. In our institution, HFNC is used only in the emergency department, the NICU, and the PICU.

Data Collection and Definitions

Study participants were identified from local Virtual PICU (Virtual PICU Systems, Los Angeles, CA) data. The Virtual PICU database provided demographic data and the Paediatric Index of Mortality 2 (PIM2) risk of mortality (ROM), a severity of illness score.[16] The electronic medical record was then queried for additional demographics, physiologic data, respiratory support, feeding practices, and documented AEs related to feeding. Participants were labeled as respiratory syncytial virus (RSV) positive if a nasopharyngeal swab tested positive by polymerase chain reaction and RSV negative if the polymerase chain reaction test was negative or if testing was not done.

Nasal cannula respiratory support was defined as unconditioned oxygen, at flow rates of ≤2 liters per minute (lpm), delivered through a standard cannula. HFNC was defined as heated, humidified oxygen at flow rates of ≥2 lpm delivered through a Vapotherm (Vapotherm, Exeter, NH) or Fisher & Paykel (Fisher & Paykel Healthcare, Inc, Irvine, CA) system.[17] Data collected at time of enteral feeding initiation included physiologic data and the route of feed (per os [PO], nasogastric [NG], nasoduodenal [ND], or gastrostomy tube [GT]). The maximal oxygen flow, predominant route of feed, and documented feeding-related AEs were recorded for each 8-hour nursing shift (06:00–14:00, 14:00–22:00, 22:00–06:00). AEs were extracted from the "Communication" section of our electronic medical record, which is the primary mode of documenting untoward patient events on an hourly basis. Based on details in the nursing documentation, AEs were then post hoc categorized as "respiratory distress" or "emesis." "Respiratory distress" was classified only as a feeding-related AE if the nursing documentation specifically linked the occurrence with a feed. An example of such documentation is, "While PO feeding [patient] had 2 episodes of desating [sic] . . . holding on further PO feeding at this time." For clarification, the daily progress notes were queried for more details, if necessary.

Subjects fed within the first 2 nursing shifts (16 hours) after PICU admission were placed in the "early feeding" group. All other subjects were classified as the "late feeding" group. At the time of this study, the decision to begin enteral feeds was not protocolized and was based solely on clinician judgment. Formal feeding evaluations were not done routinely before feed initiation but may have been done at the clinicians' discretion.

Inclusion and Exclusion Criteria

All charts of children ≤24 months old admitted from September 1, 2013 through April 30, 2014 with a primary diagnosis of bronchiolitis were reviewed. Children who received enteral nutrition after HFNC initiation were included in the study. Patients were excluded if enteral nutrition was initiated only during invasive MV and not before intubation. One subject who was fed while on HFNC and subsequently intubated in the operating room for an elective procedure was excluded.

Outcome Measures

The primary outcome measure was the incidence of feeding-related AEs, defined post hoc as "respiratory distress" or "emesis," based on hourly bedside nursing documentation and daily progress notes, as needed. Other outcome measures included PICU and hospital length of stay, duration of HFNC support, duration of supplemental oxygen support for the entire hospitalization, and total hospital charges.

Statistical Analysis

Analyses were conducted in SigmaPlot 12.5 (Systat Software, Inc, San Jose, CA). Descriptive statistics were used to analyze demographic data, feeding-related AEs, feed route, and respiratory support at feed initiation and are presented as proportions. Continuous data are presented as median values with interquartile ranges (IQRs). Categorical data are presented as numbers and percentages. χ^2 test was used to compare the incidence of AEs that occurred at varying levels of respiratory support. Mann–Whitney test was used to compare clinical outcomes between the "early feeding" and "late feeding" groups and outcomes in patients with and without a documented AE. A 2-sided P value of $<.05$ was considered statistically significant.

RESULTS

A total of 145 children ≤24 months old were admitted to the PICU with a primary diagnosis of bronchiolitis between September 2013 and April 2014 (Fig 1). HFNC was not used in 48 children, and enteral nutrition was initiated only during MV in 26 cases. These subjects were removed from analysis. One patient was excluded because endotracheal intubation was performed for a planned surgical procedure. Among the remaining 70 children who received HFNC and enteral nutrition, 1 needed endotracheal intubation and 69 did not. Demographics are shown in Table 1. The median age of the 70 children included in the final analysis was 5 (IQR 2–10) months. RSV was identified in 39% of cases. Enteral nutrition was initiated at a median of 24 (IQR 11.8–41.0) hours after admission and was provided mostly orally. Five children (7%) received NG or ND feeds,

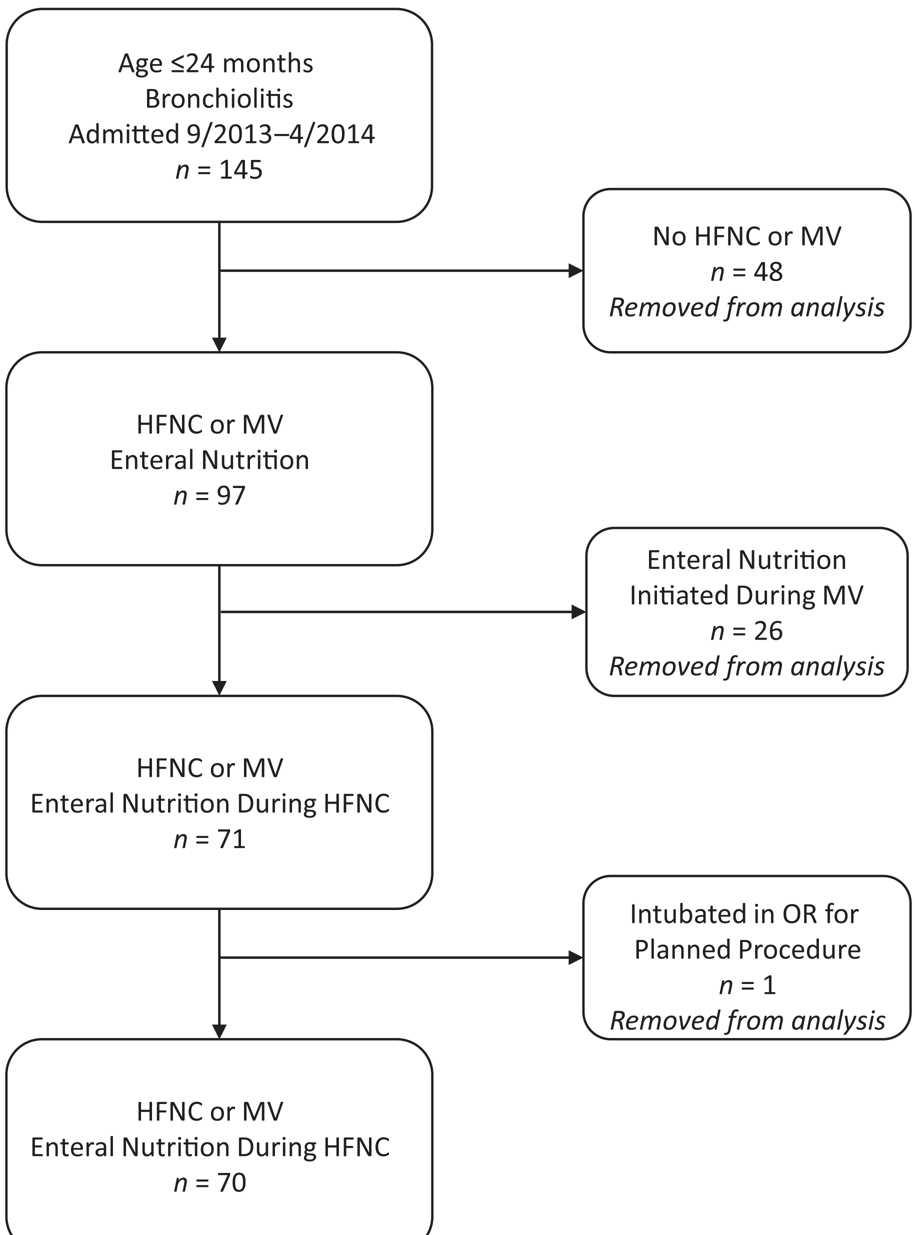

FIGURE 1 Patient inclusion and exclusion flowsheet. OR, operating room

TABLE 1 Patient Demographics and Clinical Outcomes

Age, mo (*n* = 70)	5 (IQR 2–10)
Wt, kg	7.1 (IQR 5.2–9.1)
Sex	
Female	23 (33%)
Male	47 (67%)
Race	
White	38 (54%)
Black	29 (42%)
Other	3 (4%)
RSV positive	27 (39%)
Prematurity	16 (23%)
Hospital length of stay, d	5.5 (IQR 4.0–8.3)
PICU length of stay, d	3.1 (IQR 2.2–4.5)
Duration of HFNC, h	47.5 (IQR 25.8–81.0)
Duration of supplemental O_2, h	85.0 (IQR 57.5–115.0)

and 3 children (4%) received GT feeds. The level of respiratory support provided at feed initiation varied widely, with flow rates of 2 to 4 lpm when feeding was initiated in 27 of 70 (39%) of subjects, 5 to 6 lpm in 21 of 70 (30%) of subjects, and ≥7 lpm in 9 of 70 (12%). The remaining 13 patients were not fed until HFNC support was discontinued. AEs related to feeding occurred rarely. The 70 included patients provided data for 794 8-hour nursing shifts. Children were fed in 501 of 794 (63%) shifts, with AEs documented in only 29 of 501 (6%) shifts with a feed. Of the 501 shifts with a feed, on 67 shifts the child was fed via NG, ND, or GT, and on 434 shifts the child was fed PO. There was no difference in AE rate between NG, ND, or GT feeds and PO feeds (1.5% vs 6.5%, $P = .181$). The 29 AEs occurred in 18 patients; in 10 patients there was only 1 documented AE, 6 patients had 2 documented AEs, and there were 3 or 4 AEs documented for 1 patient. In the 2 patients with ≥3 AEs, all AEs were emesis, and all occurred while the patient was receiving ≤6 lpm HFNC respiratory support.

The most common AE was emesis (*n* = 20), followed by respiratory distress (*n* = 9). There were no documented aspirations or choking events. When a patient did experience an AE, there was a change in clinical therapy documented 8 (28%) times. The 9 episodes of respiratory distress occurred in 7 subjects, and all were subsequently made NPO. For 3 of these subjects the rate of HFNC was increased after an episode of postfeeding respiratory distress. None of the patients with a documented AE needed escalation of care to MV, and the patient who did need MV after feeding did not have a documented AE. For the 20 documented episodes of emesis that occurred in 14 patients, a change in therapy was documented only once. For that patient, feed type was changed from formula to "clears."

We found no demographic differences between patients who experienced an AE (*n* = 18) and those who did not have a documented AE (*n* = 52) (Table 2). There was no difference in age, weight, white race, male sex, RSV infection, prematurity, or PIM2 ROM. There was no difference in occurrence of earlier feeding (50% vs 25%, $P = .094$) between those with and without a documented AE. Additionally, there were no differences in clinical outcomes between the patients with and without a documented AE. Hospital length of stay, PICU length of stay, duration of HFNC use, duration of supplemental oxygen use, and total hospital charges were similar between the groups. Because prematurity is a risk factor for more severe bronchiolitis, we analyzed outcomes between patients who were and were not premature and found no significant differences. The rate of AEs did not differ significantly between patients born prematurely and those born at term (44% vs 20%, $P = .100$), and there were no differences in clinical outcomes between these 2 groups, including PICU length of stay, hospital length of stay, duration of HFNC use, and duration of supplemental oxygen use (all *P*s > .300).

We examined the respiratory support patients were receiving at the time of the documented AE (Fig 2) to investigate our primary hypothesis that rates of AE are similar at different levels of oxygen flow. We found that the incidence of AE at varying levels of respiratory support did not differ ($P = .092$). Only 1 AE occurred in a child receiving a moderate level of support at ≥7 lpm, and 11 of 29 AEs occurred after children were weaned off HFNC altogether.

Twenty-two children were fed during the first 2 nursing shifts after arrival to the PICU. These subjects were defined as the "early feeding" group; the remaining subjects (*n* = 48) were classified as the "late feeding" group. For the 70 children included in the analysis, the median time to feed was 24 (IQR 12.5–42.0) hours. The 16-hour time point was chosen to discriminate between "early feeding" and "late feeding" to capture both the children who were fed earlier than the median time to feed and a potential high-risk time point for feeds, because they were earlier in their clinical course. Among the patients in

TABLE 2 Differences Between Patients With and Without a Documented AE

	Patients With an AE (*n* = 18)	Patients Without an AE (*n* = 52)	*P*
.803	5.0 (IQR 2.0–8.0)	4.5 (IQR 2.0–10.0)	
.386	6.5 (IQR 5.2–7.5)	7.2 (IQR 5.2–9.6)	
.343	12 (67%)	26 (50%)	
.410	14 (78%)	33 (63%)	
.382	9 (50%)	18 (35%)	
.100	7 (39%)	9 (17%)	
.496	0.180 (IQR 0.160–0.205)	0.180 (IQR 0.170–0.230)	
.094	9 (50%)	13 (25%)	
.180	6.0 (IQR 4.8–9.0)	5.0 (IQR 4.0–7.0)	
.846	3.2 (IQR 2.2–4.5)	3.0 (IQR 2.1–4.5)	
.798	53.5 (IQR 19.8–84.5)	46.0 (IQR 27.3–81.0)	
.051	110.0 (IQR 73.3–154.0)	83.0 (IQR 55.0–102.0)	
Total hospital charges, $	44 164.0 (IQR 29 480.3–62 826.3)	38 979.0 (IQR 28 102.5–56 754.0)	.481

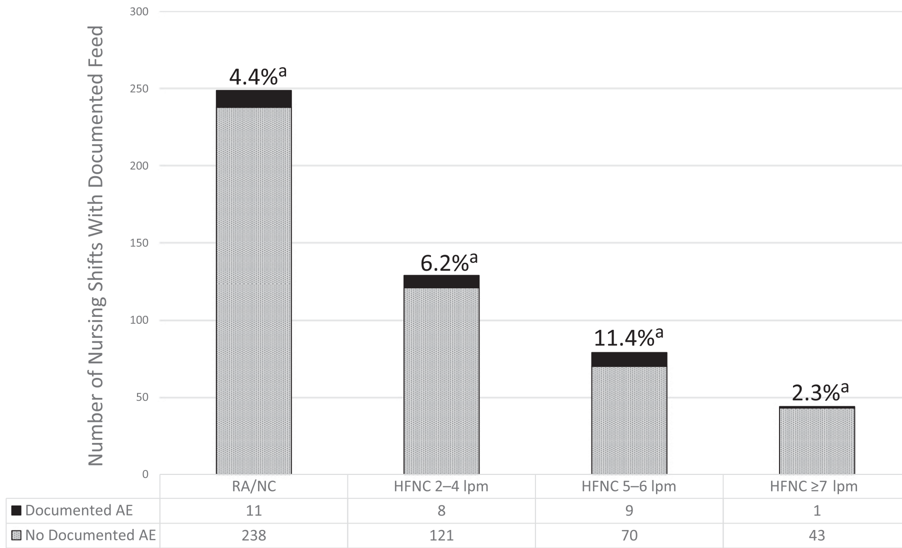

FIGURE 2 Incidence of feeding-related AEs. [a]Overall, there was no difference in the rate of AEs based on the highest level of respiratory support documented during each 8-hour nursing shift (P = .092). NC, nasal cannula; RA, room air.

the "early feeding" cohort, there was no difference in age (5.0 months [IQR 2.8–8.3] vs 4.0 [IQR 2.0–10.8], P = .703), weight (7.1 kg [IQR 5.3–9.1] vs 6.8 [IQR 5.2–9.4], P = .854), white race (55% vs 54%, P = .819), male gender (77% vs 63%, P = .343), RSV (36% vs 40%, P = .994), prematurity (27% vs 33%, P = .818), or PIM2 ROM (0.170 [IQR 0.168–0.213] vs 0.180 [IQR 0.170–0.237], P = .323) as compared with the "late feeding" subjects. The incidence of AE was similar between the "early feeding" and "late feeding" groups (41% vs 19%, P = .094). However, the "early feeding" group had a shorter PICU length of stay (2.2 days [IQR 1.4–3.9] vs 3.2 [IQR 2.5–5.3], P = .006), shorter duration of HFNC use (26.0 hours [IQR 15.8–57.0] vs 53.5 [IQR 37.0–84.8], P = .002), and less total hospital charges ($33 284.5 [IQR $17 660.3–$49 804.0] vs $42 819.0 [IQR $31 021.5–$76 491.3], P = .02), compared with children in the "late feeding" group. The hospital length of stay and hours of supplemental oxygen use were similar between the 2 groups (Table 3).

DISCUSSION

In this analysis of a single center's experience with feeding children with bronchiolitis while on HFNC, we found no association between feeding-related AEs and the concomitant level of HFNC respiratory support. Previous studies investigating the success of enteral nutrition and HFNC use include premature infants with respiratory distress syndrome.[18–20] This is the first study designed specifically to evaluate AEs encountered during enteral feedings in children admitted to the PICU with bronchiolitis and managed with HFNC. We chose this group specifically because of the high prevalence of children with bronchiolitis in the PICU and the increasing use of HFNC for this patient population.[10–14] Though preliminary, our findings suggest that enteral feeding while on HFNC can be delivered safely. Of the 145 children ≤24 months old admitted to the PICU with a primary diagnosis of bronchiolitis, 19 were intubated in the PICU after being treated with HFNC. Only 1 (5.2%) received enteral feeds while on HFNC, and that patient was made NPO 28 hours before initiation of MV. The absence of a feeding-related AE for this patient and the prolonged interval between the last feed and time of intubation suggests that the feeding played little role. However, it is possible that the child had microaspiration or undocumented aspiration that led to delayed worsening and subsequent respiratory failure. For the 70 children who were fed while receiving HFNC, AEs were rare, occurring on 5.8% of all nursing shifts with a documented enteral feed. Furthermore, there was no relationship between the AE and level of HFNC respiratory support. In fact, 11 (33%) of the documented AEs occurred after the patient was weaned from HFNC altogether.

All children in this study were fed enterally during their PICU stay, and feeds were initiated a median of 24 hours after admission. Based on the lack of strong evidence supporting the use of routine medical interventions in the management of children hospitalized with bronchiolitis, the American Academy of Pediatrics clinical practice guidelines make no recommendations other than supportive

TABLE 3 Differences in Clinical Outcomes Based on Timing of Feed Initiation

	Early Feeding Group (n = 22)	Late Feeding Group (n = 48)	P
PICU length of stay, d	2.2 (IQR 1.4–3.9)	3.2 (IQR 2.5–5.3)	.006
Hospital length of stay, d	5 (IQR 3–6)	6 (IQR 4–9)	.08
Duration of HFNC, h	26.0 (IQR 15.8–57.0)	53.5 (IQR 37.0–84.8)	.002
Duration of supplemental O_2, h	83.5 (IQR 39.0–112.3)	85.0 (IQR 63.0–142.0)	.33
Hospital charges, $	33 284.5 (IQR 17 660.3–49 804.0)	42 819.0 (IQR 31 021.5–76 491.3)	.02

care.[2] However, optimizing and standardizing nutrition delivery may be an important way to improve clinical outcomes in infants and children with bronchiolitis.[21] In our study, we found that children who were fed earlier in their PICU admission had shorter duration of HFNC use, shorter PICU length of stay, lower total hospital charges, and a trend toward shorter hospital length of stay. Although these findings may be secondary to treatment bias (children less ill were deemed safe to feed at earlier time points) the data align with previous studies showing an association between early enteral nutrition in critically ill children and improved clinical outcomes.[22,23] Several other studies have investigated clinical outcomes and their relation to nutrition in children with bronchiolitis.[6,7,24] Weisgerber et al[7] retrospectively reviewed the nutrition data for infants with bronchiolitis admitted to a single center and found a significant correlation between diminished caloric intake early in hospitalization and prolonged hospital length of stay. Future studies could evaluate the incorporation of early feeding in a bronchiolitis care path in the PICU to reduce hospital length of stay and hospital costs.

There are several limitations to this study. This was a retrospective review, and data collection was limited to information available in the electronic medical record. Documentation of feeding-related AEs requires both the recognition of an event by the nurse and the decision to include it in the medical record; therefore, our rate of AEs may be falsely low. However, this should be similarly true at all levels of HFNC support, so our finding that there was no association between HFNC level and AE rate is less likely to be affected. The retrospective design also precludes a power analysis, so the study may be underpowered for the outcome of interest; a larger, prospectively designed trial may support our finding that feeding-related AEs are not associated with level of HFNC respiratory support.

The study population is small and includes 1 center's experience during a respiratory season representing the management style of 1 PICU, which may limit study outcome generalizability. Our PICU does not currently have a protocol for the use of HFNC such that the decision to initiate, escalate, and wean HFNC is driven by clinician judgment. Therefore, the rate of HFNC may not necessarily reflect the severity of illness. Likewise, initiation of feeding is not protocolized, with the decision to feed based on clinician preference. The retrospective nature of this study precludes the use of a respiratory score to compare illness severity between groups. Although the PIM2 ROM was prospectively collected and obtained from the Virtual PICU database, its use in this particular population of patients with bronchiolitis necessitating HFNC is limited[13] and has not been validated.

We did not stratify patients into subgroups based on comorbidities, age, feeding route, or illness severity. Demographics, including the PIM2 ROM, were similar between patients who did and did not have a documented AE, but the groups were small. It is possible that younger and sicker patients may have more feeding-related AEs, but a larger sample size is needed for such subgroup analysis. Similarly, although the AE rates between patients fed PO versus the NG, ND, or GT route were similar, for this study there were probably too few subjects to make meaningful conclusions. The NG, ND, or GT feeding route may be safer because of decreased laryngeal penetration and aspiration as compared with the PO feeding route, but future prospective investigations must include a larger sample size than present in this study.

CONCLUSIONS

This is the first study to evaluate the incidence of feeding-related AEs in children with bronchiolitis needing HFNC. In this small patient cohort at a single institution, AEs were rare and not related to the delivered level of HFNC respiratory support. Children who were fed earlier in their PICU admission had shorter PICU stays and significantly lower hospital charges. Future research, such as a prospective randomized interventional trial, is warranted to establish whether early initiation of enteral nutrition improves clinical outcomes in bronchiolitis patients receiving HFNC.

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