Enteral Feeding for Children on Bilevel Positive Pressure Ventilation for Status Asthmaticus

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Abstract

A retrospective data analysis was conducted to evaluate enteral nutrition practices for children admitted with status asthmaticus in a single-center pediatric intensive care unit. Of 406 charts, 315 were analyzed (63% male); 135 on bilevel positive airway pressure ventilation (BIPAP) and 180 on simple mask. Overall median age and weight were 6.0 (interquartile range [IQR]: 6.0) years and 24.8 (IQR: 20.8) kg, respectively. All children studied were on full feeds while still on BIPAP and simple mask; 99.3 and 100% were fed per oral, respectively. Median time to initiation of feeds and full feeds was longer in the BIPAP group, 11.0 (IQR: 20) and 23.0 hours (IQR: 26), versus simple mask group, 4.3 (IQR: 7) and 12.0 hours (IQR: 15), $p = 0.001$. The results remained similar after adjusting for gender, weight, clinical asthma score at admission, use of adjunct therapy, and duration of continuous albuterol. By 24 hours, 81.5% of patients on BIPAP and 96.6% on simple mask were started on feeds. Compared with simple mask, patients on BIPAP were sicker with median asthma score at admission of 4 (IQR: 2) versus 3 (IQR: 2) on simple mask, requiring more adjunct therapy (80.0 vs. 43.9%), and a longer median length of therapy of 41.0 (IQR: 41) versus 20.0 hours (IQR: 29), respectively, $p = 0.001$. There were no complications such as aspiration pneumonia, and none required invasive mechanical ventilation in either group. Enteral nutrition was effectively and safely initiated and continued for children admitted with status asthmaticus, including those on noninvasive bilevel ventilation therapy.

Keywords
- pediatric
- enteral nutrition
- bilevel positive pressure ventilation
- noninvasive ventilation
- asthma
- status asthmaticus

Introduction

In the United States, asthma is the third leading cause of hospitalization in children under 15 years of age.[1] Status asthmaticus (SA), defined as failure of conventional medical therapy during the management of asthma leading to respiratory failure, remains one of the leading causes for admission to the pediatric intensive care unit (PICU).[2,3]

While there is a lack of convincing data demonstrating decrease in intubation or mortality with the use of noninvasive positive pressure ventilation (NPPV) for critically ill children admitted with SA,[4] there is increasing evidence of expansive use of NPPV for this condition in recent years.[5,6] However, NPPV has also come with its challenges including being independently associated with delayed initiation of enteral nutrition (EN).[7,8] There is an increased concern for potential complications of feeding intolerance, aspiration, and subsequently pneumonia that may lead to a reluctance in initiating EN despite the known benefits of early EN in critically ill children.[9,10] Moreover, there is a general concern

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regarding which patients may potentially fail NPPV and eventually require endotracheal intubation, adding to the hesitancy in initiating EN.

There are a few studies detailing the benefits of early EN on infection prevention, clinical outcomes, and lower hospital charges in the general critically ill pediatric population.[11,12] However, there is limited data on the safety and feasibility of providing EN to patients admitted with SA receiving respiratory support via NPPV in the form of bilevel positive pressure ventilation (BIPAP). The need to determine feasibility of EN in children with SA on BIPAP is important, and differs from other respiratory failure cases needing the same, because children with SA on BIPAP recover faster and rarely progress to requiring invasive mechanical ventilation.[5] Therefore, they may be more likely to benefit from early EN and should be studied separately. The goal of this study was to describe our institutional practice of initiating EN to critically ill children admitted with SA in the PICU on BIPAP, assess how it differs from children requiring just simple mask, and to determine the incidence of adverse events (AE) related to feeding, if any.

Materials and Methods

Study Design

A retrospective chart review was done on all children (2–18 years old) admitted with the diagnosis of severe asthma to the PICU at St John's Children's Hospital, a tertiary unit in Springfield, Illinois, from December 2010 to December 2016. Inclusion criteria included children between the ages of 2 to 18 years admitted with International Statistical Classification of Diseases, 10th revision (ICD-10) Code of "Status Asthmaticus" or "Severe Asthma" requiring oxygen supplementation in the form of either simple face mask or NPPV with BIPAP. Patients who were determined not to have asthma after admission to the PICU or those who did not have consistently documented clinical asthma scores (CAS) were excluded. Additionally, children with a known history of developmental delay, cerebral palsy, cardiac pathology, and tracheostomy or ventilator dependence were also excluded. The local Institutional Review Board (Springfield Committee on Research Involving Human Subjects) waived the need for informed consent and approved the study.

Status Asthmaticus Management Protocol

In July 2010, a protocol was instituted in the PICU at St John's Children's Hospital where children admitted with SA were managed by respiratory therapists according to their CAS.[2] CAS, which has been used at our institution for several years, is a modified version of the validated 5-point Pediatric Asthma Severity Score[13] taking into account respiratory rate, work of breathing/accessory muscle use, air exchange, wheezing severity, and I:E ratio (►**Table 1**). According to the protocol, children were placed on BIPAP if their initial CAS was 4 on admission to the PICU, or if the score increased despite 2 hours of standard therapy (continuous albuterol, systemic steroids, and oxygen therapy via simple mask). If CAS did not decrease after 2 hours of the addition of BIPAP, adjunct therapy, including magnesium sulfate and helium-oxygen mixture, could be instituted; and finally, invasive mechanical ventilation, if needed. BIPAP was always initiated at pressure support of 8 cm H20, titrated to maintain a tidal volume of 6 to 8 mL per kilogram body weight, and positive end expiratory pressure of 5 cm H20, increased as needed for work of breathing. Ten to 15 L per minute flow rate was used to drive albuterol when simple face mask was required. The children who needed BIPAP were first taken off BIPAP 2 hours prior to being weaned off continuous albuterol.

Table 1 Clinical asthma score

Parameters	Clinical asthma scores
Respiratory rate	0) Normal 1) Above tachypnea threshold for age
Accessory muscle use	0) Normal/none 1) Subcostal/intercostal 2) Neck and abdominal
Air exchange	0) Normal 1) Localized/decreased 2) Generalized/decreased
Wheezing	0) End expiratory /none 1) Entire expiration 2) Entire inspiration/expiration
I:E ratio	0) $\leq$1:2 (normal) 1) >1:3 (prolonged exp)

Feeding Regimen

As per the protocol, after 2 hours on BIPAP or simple mask, all patients could be started on EN either per oral or via nasogastric tube, liquid diet advanced as tolerated, provided patient's respiratory status remained stable or improved as reflected by the trend in their CAS. Furthermore, it was imperative that children tolerated removal of mask for the short period of time needed for them to eat or drink, without signs of increasing respiratory distress. They were then placed back on the masks immediately after feeding. However, the decision to feed was at the discretion of the attending physician. Feeding-related AE included aspiration leading to pneumonia, emesis after feeding, and documented increase in work of breathing after feeding. Full EN was defined as at least 100% of volume requirement prescribed by the managing team, that is, when intravenous fluid was either discontinued or decreased to "keep vein open (KVO)."

Data Collection and Outcome Measures

Demographic data, type of respiratory support (BIPAP, or simple mask) time to initiation of EN, time to full EN, modes of EN (nasogastric or per oral), time on BIPAP or simple mask, CAS, adjunct treatments, duration of continuous albuterol, and AE related to feeding were obtained from medical records. Data on AE included escalation of respiratory support, incidence of pneumonia not present on admission, and feeding intolerance as evidenced by emesis or need to withhold feeds. Data was extracted and recorded every 2 hours for the duration the patient was in the PICU. Outcome measures were time to initiation of EN, time to full EN, and AE related to EN.

Statistical Methods

Categorical variables are reported in counts and proportions with chi-squared analysis performed. Continuous variables are reported with median. The IQR that is reported with median stands for the interquartile range, which is the difference between the 25th percentile and the 75th percentile. Wilcoxon (Rank Sum) nonparametric analysis was conducted for the continuous variables. Analysis of covariances with least square means follow-up was ran to adjust for gender, weight, CAS at admission, use of adjunct therapy, and PICU length of stay (LOS), and hospital LOS. Regression analysis was used to calculate the R2. A 2×7 analysis of variance was conducted to compare the two study groups over the 7 years of the study. SAS 9.4 statistical software (Cary, North Carolina, United States) was used and statistical significance was determined using two-sided p-value <0.05.

Results

There were 406 cases admitted with ICD-10 Code of "Status Asthmaticus" or "Severe Asthma" to the PICU, out of which 43 did not have a diagnosis of asthma and 48 were not consistently scored for clinical severity during the PICU stay. Therefore, a total of 315 cases were included in the study, of which 135 required oxygen supplementation through BIPAP and 180 were placed on simple mask. Demographic data are presented in ►**Table 2**. Overall median age was 6 (IQR: 6) years and was similar in both groups. Overall median weight was 24.8 (IQR: 20.8) kg, greater in the BiPAP group, $p = 0.02$. There were more females on BIPAP, $p = 0.037$.

Severity of Asthma in the PICU (►Table 2)

Overall CAS at admission to the PICU was median 3 (IQR: 2), compared with simple mask, patients on BIPAP were sicker, $p = 0.001$. A total of 58.4% cases required adjunctive therapy including magnesium sulfate infusion and/or helium-oxygen mixture. Children requiring BIPAP received more adjunctive therapy, $p = 0.001$. Overall duration of continuous albuterol therapy and hospital LOS were median 26 (IQR: 39) and 67 (54) hours, respectively; both were significantly longer in children requiring BIPAP, $p = 0.001$. None of the patients required any sedation to facilitate BIPAP.

Enteral Nutrition (►Table 3)

All children studied were on full EN while still on BIPAP and simple mask; 99.3 and 100% were fed per oral, respectively. One child was fed via nasogastric tube and one via G-tube in the BIPAP group. Overall median time to initiation of EN and full EN was 6 (IQR: 11) and 15 (IQR: 17) hours, respectively. Both were longer in the BIPAP group versus simple mask group, $p = 0.001$. The results remained similar after adjusting for gender, weight, CAS at admission, use of adjunct therapy, and duration of continuous albuterol. The r2 for "time to initiation of EN" and "time to full EN" were 0.16 and 0.27, respectively, while using the parametric data for age, gender, CAS at admission, use of adjunct therapy, and duration of continuous albuterol as predictors. By 24 hours, 81.54% of patients on BIPAP and 96.6% on simple mask were started on EN, $p = 0.001$.

None of the patients required invasive mechanical ventilation. Additionally, there were no documented AE, including aspiration leading to new pneumonia (pneumonia not present on admission), emesis, and documented increase in work of breathing related to feeding itself or removal of mask for feeding, in either group.

Over the years, the duration gap between patients on BIPAP versus simple mask for time to initiate EN (►**Fig. 1**) and reach full EN decreased (►**Fig. 2**). In fact, time to initiate feeds was statistically similar in the year 2016, median 6 (IQR: 21) hours in the BIPAP group versus median 5.5 (IQR: 9) hours in the simple mask group, $p > 0.05$.

Discussion

In this retrospective cohort study, all children admitted to the PICU with a diagnosis of SA were started on EN while still receiving respiratory support via BIPAP or facemask with 90% of patients on full EN within 24 hours of admission. Children who are critically ill are under metabolic stress and EN plays a vital role in recovery. Several recent studies have highlighted the significance of early EN in the critically ill pediatric

Table 2 Demographic data and severity of status asthmaticus in the PICU

Characteristics	Overall median (IQR) $n = 315$	Bilevel positive pressure ventilation group Median (IQR) $n = 135$	Simple mask group Median (IQR) $n = 180$	p-Value
Age (y)	6 (6)	7 (6)	6 (6)	NS
Weight (kg)	24.8 (20.8)	26.8 (23)	24.0 (19)	0.02
Females (%)	36.6	43.7	32.3	0.037
Asthma score at admission	3 (2)	4 (2)	3 (2)	0.001
Adjunctive therapy (%)	58.4	80	43.9	0.001
Duration of continuous albuterol (h)	26 (39)	41 (41)	20 (29)	0.001
Hospital length of stay (h)	67 (54)	87 (57)	53 (45)	0.001

Abbreviations: IQR, interquartile range; NS, not specified; PICU, pediatric intensive care unit.

Table 3 Enteral nutrition

Characteristics	Overall median (IQR) $n = 315$	Bilevel positive pressure ventilation group Median (IQR) $n = 135$	Simple mask group Median (IQR) $n = 180$	*p*-Value
Patients receiving enteral nutrition (%)	100	100	100	NS
Time to initiate feeds (h)	6 (11)	11 (20)	4.3 (7)	0.001
Time to reach full feeds (h)	15 (17)	23 (26)	12 (15)	0.001
Patients started on feeds by 24 hours (%)	89.2	81.5	96.6	0.001

Abbreviations: IQR, interquartile range; NS, not specified; PICU, pediatric intensive care unit.

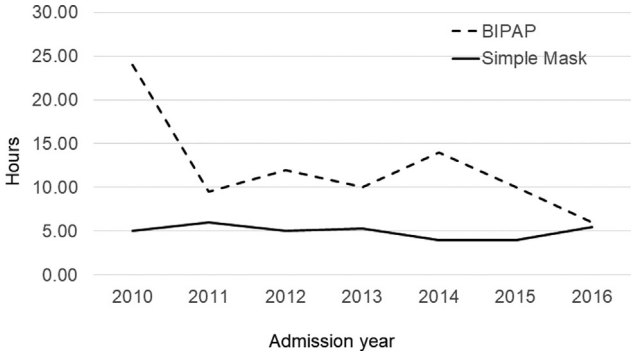

Fig. 1 Time to initiate enteral nutrition. BIPAP, bilevel positive airway pressure ventilation.

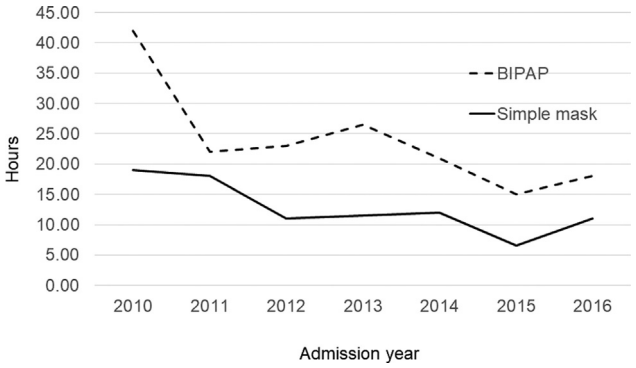

Fig. 2 Time to full enteral nutrition. BIPAP, bilevel positive airway pressure ventilation.

population including its role in shorter PICU and overall LOS.[11,14–16] There does not appear to be a consensus, however, on the definition and recommendation for early EN and has been stated in the past as anywhere from 24 to 48 hours.[8]

While there is plenty of published literature describing EN practices for critically ill children in general,[12,17] there is a paucity of data on early EN in patients on NPPV, specifically those admitted with SA. To the best of our knowledge, our study is the first to focus on safety of EN on children with SA admitted to the PICU on BIPAP. One large French observational study reported that almost 60% of adults with respiratory failure due to various reasons on NPPV were starved for over 48 hours and only 2.5% received EN.[18] Another large annual cross-sectional, multinational audit conducted over 7 years demonstrated that among almost 10,000 patients admitted with respiratory failure (out of which 6.2% were on NPPV and the rest on invasive mechanical ventilation), 40 and 20% were not fed the first and second days of admission, respectively, while on respiratory support.[19] There are fewer studies in children. In a retrospective cohort study, Leroue et al described 64% of all children on NPPV were initiated on EN within the first 24 hours with 54% fed orally. However, only 32% were on BIPAP and only 18% had a diagnosis of SA.[7] Recently, a retrospective study in four PICUs across four European nations studying EN practices in children on various forms of NPPV around intubation reported a median time to initiate feeds of 4 hours. However, only 10.8% fed per oral, only 33.2% were on BIPAP, and it is unclear if there were any children admitted with SA.[20]

Even though 81.4% of cases on BIPAP in our study were on EN within 24 hours, and 100% eventually received full EN while still on BIPAP, it was noted that the time to achieve both was longer in the BIPAP group than the simple mask group. This is intuitive and can be attributed to increased severity of illness as evidenced by higher asthma scores, longer requirement of continuous inhaled albuterol, and use of adjunctive therapy in the former group. Children needed to be able to tolerate removing their BIPAP masks long enough to eat, as almost 100% of cases received EN by oral route. Additionally, the hesitancy in initiating EN in the BIPAP group may have been to better determine the likely clinical course to avoid complications of intubation on a full stomach.[21] Use of NPPV has previously been shown to be independently associated with a delay in initiating EN predominantly due to fear of feeding-related complications, and difficulty in anticipating which cohort of patients may need escalation of support and intubation.[22] In one retrospective cross-sectional study looking at barriers to early initiation of EN in children under 21 years of age in six PICUs, the OR of delayed EN in children on NPPV compared with no support was 3.37 (95% confidence interval: 1.69–6.72).[17] As providers in our hospital became familiar with NPPV for SA, the time to initiate EN and reach full EN shortened over the years.

Our study revealed no feeding-related complications namely aspiration pneumonia or need for mechanical ventilation, contrary to the large French observational study that reported nosocomial pneumonia and increased mortality rates in adults receiving EN on NPPV.[18] There are a few studies in children that have reported some AE. Tume et al in their European study across four PICUs found the most common complications related to EN on noninvasive

ventilation to be gastrointestinal in nature (4–20%) with rare incidence of aspiration pneumonia.[20] However, as we discussed earlier, only 33% of their patient population was on BIPAP ($n = 108$) and their admission diagnosis was varied. Leroue et al demonstrated 12% AE in the cohort of children on NPPV that they studied, including 10% of patients having developed a new pneumonia and 3% of patients requiring endotracheal intubation.[7] However, it is not clear what type of noninvasive support was related to AE (high flow nasal canula [HFNC], continuous positive airway pressure, or BIPAP), and whether the 18% children admitted with SA actually incurred any AEs. One pediatric study reported 5.8% of patients experienced EN-related AEs when placed on HFNC.[23] However, this study was on children under 24 months of age admitted for bronchiolitis.

It would be remiss not to discuss the use, or lack thereof, of HFNC in this retrospective review. HFNC therapy had just been introduced as respiratory support during the early years of this study, mainly in neonates in the neonatal intensive care units and infants with bronchiolitis.[24] Although it was an emerging mode of respiratory support, there was a lack of clinical experience and studies in older children.[25] Between the years 2010 and 2016 (the duration of this review), there was no documented use of HFNC to manage children admitted to the PICU with SA in our hospital.

Our study has several limitations to consider when interpreting these results. Due to the retrospective nature of the study, data collected was limited to prior documentation. Data on AEs was also extracted from documentation and some, albeit minor AEs, could have been missed. Having said that, the data was recorded every 2 hours in the PICU and feeding data was well documented by nursing staff. We were also limited by our inability to accurately assess oral intake and protein/calorie requirements. Hence, we used weaning off intravenous fluids as a surrogate marker for reaching full EN. Intravenous fluids could have been continued even after full EN was reached, thus erroneously decreasing the data on overall time to reach full EN. Nonetheless, even with this limitation, almost 90% children were on full EN at 24 hours. Another limitation we noted was that even though the protocol for management of SA had guidelines for initiation for EN, the ultimate decision was at the discretion of the attending physician and, therefore, not standardized. As "improved PO intake" is subjective, this may have also been influenced by provider comfort levels and therefore the time to reach full EN likely represents selection bias. Additionally, we lacked information regarding provider-specific factors contributing to the clinical decision-making regarding EN. Finally, this study included a small cohort of patients and it represents a single institution's experience and unknown accuracy of generalizability to others. As a result of the nature of the study, the question of EN affecting PICU and hospital LOS could not be determined. Another important aspect of EN is patient and family satisfaction that also could not be determined because of the retrospective nature and lack of data. A larger trial comparing children admitted with SA receiving full EN versus no EN may be required to answer these questions.

Conclusions

EN is a cornerstone of management and recovery in the PICU. Since most children admitted for SA recover early and rarely proceed to requiring endotracheal intubation and invasive mechanical ventilation, early EN may be more feasible than in children admitted with respiratory failure for other etiologies. Our institutional experience suggests that EN may be effectively and safely initiated and continued for children admitted with SA on both simple mask and BIPAP. Although early oral nutrition intuitively results in a "happy child" and satisfied parents, this warrants further research. Larger studies are also needed to determine if initiating EN within 24 hours affects time to recovery.

Note

This work was performed at St. John's Children's Hospital, Southern Illinois University School of Medicine in Springfield, IL.

Conflict of Interest

None declared.

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