Impact of SIMPLE Feeding Quality Improvement Strategies on Aerodigestive Milestones and Feeding Outcomes in BPD Infants

Roopali Bapat, MD, Ish K. Gulati, MD, Sudarshan Jadcherla, MD

ABSTRACT

BACKGROUND AND OBJECTIVES: Delays with enteral and oral feeding milestones among premature infants with bronchopulmonary dysplasia (BPD) can be due to provider variation or infant-dependent factors. Our objectives with this study were to compare aerodigestive milestones and length of stay in BPD infants after implementing a quality improvement program to improve feeding outcomes.

METHODS: Using the Institute for Healthcare Improvement model for quality improvement, we implemented the simplified, individualized, milestone-targeted, pragmatic, longitudinal, and educational (SIMPLE) feeding strategy to enhance feeding and aerodigestive milestones among BPD infants. The key interventions addressed were as follows: (1) enteral feed initiation and advancement protocol; (2) oral feeding progression guidelines, optimization of respiratory support, feeding readiness scores, nonnutritive breastfeeding, and cue-based feeding; (3) active multidisciplinary collaboration; and (4) family-centered care. Comparisons were made between baseline (January 2009 to March 2010) and SIMPLE feeding strategy (May 2010 to December 2013) groups. Both groups included infants between 23 0/7 and 32 6/7 weeks’ birth gestation, and ≥34 weeks’ postmenstrual age at admission and discharge.

RESULTS: The baseline group and SIMPLE feeding group included 92 patients and 187 patients, respectively. Full enteral feeding, first oral feeding, full oral feeding, and length of stay milestones were (all P < .05) achieved sooner in the SIMPLE feeding group. Although the overall prevalence of BPD in the 2 groups is similar, the incidence of moderate BPD has decreased (P < .05) and severe BPD has increased (P < .05) in the SIMPLE feeding group.

CONCLUSIONS: SIMPLE feeding strategy advances postnatal maturation and acquisition of feeding milestones irrespective of the severity of BPD and impacts the length of stay, thereby lowering resource use.
Airway and digestive morbidities are common consequences among hospitalized premature infants with bronchopulmonary dysplasia (BPD). These morbidities further complicate an infant’s ability to feed, thus contributing to significant delays in the timely acquisition of feeding milestones. Infants with BPD may have an increased risk of gastroesophageal reflux and other comorbidities, such as dysphagia, esophageal dysmotility, delayed gastric emptying, and neuropathology. In such situations, the metrics to measure feeding difficulties may be attributed to delayed acquisition of independent enteral or oral feeding milestones or a lack of progressive tolerance of increasing feeding volumes. Although nutrition plays a central role in optimizing growth and management of BPD, the methods to provide nutrition are equally important from the perspective of enhancing independence of oral skills. However, the acquisition of aerodigestive milestones remains a major conundrum for hospital discharge, and the barriers can either be provider or infant dependent. This remains a major problem for conditions with heterogeneity such as BPD, the definition of which continues to evolve during postnatal growth in terms of presence, timing, and severity.

Although there was an understanding of the heterogeneity of BPD and of feeding difficulties, there was a clear lack of standardization in how different care providers paid attention to independent feeding skills and milestones. To address this variability in practice, we developed a simplified, individualized, milestone-targeted, pragmatic, longitudinal, and educational (SIMPLE) feeding strategy, a highly refined quality improvement (QI) project to enhance attainment of feeding and developmental milestones in NICU infants. Because BPD is a major unique phenotypic group of all premature infants, we evaluated if our SIMPLE program made any impact on this specific BPD population. In this article, we describe how the SIMPLE QI project made an impact, if any, on the aerodigestive milestones and outcomes in BPD infants.

**METHODS**

Our NICU is managed by 57 neonatologists, 95 neonatal nurse practitioners, 3 hospitals, 9 neonatal fellows, and >300 registered nurses rotating through the NICU, all with varying skills and experience. The SIMPLE feeding team consists of a core group of 3 neonatologists, 2 nurse practitioners, 3 nurses, 2 nutritionists, 2 occupational therapists, 2 lactation consultants, 1 pharmacist, and 1 speech therapist. Ours is an all-referral tertiary care level IV unit, receiving admissions from all over central Ohio. Generally, infants who are sick and/or premature are transferred to our NICU from the delivery hospitals. Thus, age at referral as well as the acuity can be highly variable.

**Timeline**

Baseline population (January 2009 to March 2010) included 92 patients, of which 63 had BPD; the intervention group (June 2010 to December 2013) had 187 patients, of which 135 had BPD. There was 3 months of initial teaching and training before launching the SIMPLE feeding program.

The baseline population was a historical control and hence remained the same for the previous publication as well as for this article. However, we had 2 separate programs: one meant for simple feeding difficulties needing minimal or no respiratory support and the other for infants with positive-pressure support, higher FiO₂, and flow needs (BPD group). In this report, we describe the data on the BPD group. During this process, we realized that improvement in oral feeding outcomes in the BPD population required QI measures specific for the BPD population.

**Interventions**

Our group has previously described the key drivers and interventions. The key driver diagram for the BPD-specific population is shown in Fig. 1. Specific to BPD, infants’ needs have been addressed during the personalized feeding rounds. SIMPLE feeding strategy was implemented as a QI project to primarily minimize variations in nutrition and feeding practices and also to improve compliance.

Hence, some key drivers and interventions that were specifically addressed (indicated in the key driver diagram and annotated in control chart) are as follows:

1. **Enteral feeds:** Guidelines regarding feeding initiation and advancement practices were generated; compliance to these guidelines was monitored on a daily and weekly basis, and there was daily evaluation of need for parenteral nutrition.

2. **Oral feeds:** Guidelines for feeding strategies on all respiratory support and feeding on continuous positive airway pressure (CPAP). Feeding readiness scores, pacifier dipped in milk trials, kangaroo care, nonnutritive and nutritive breastfeeding, and cue-based feeds.

3. **Multidisciplinary collaboration:** Weekly multidisciplinary rounds are conducted encompassing a group of physicians specializing in SIMPLE feeding program approaches: residents, fellows, neonatal nurse practitioners, nurses, occupational therapists, physical therapists, lactation specialists, and nutrition specialists and parents. Also included are accurate growth measurements using the length board, evaluating weekly measurements of length, weight, and fronto-occipital circumference (FOC).

4. **Parent-centered care:** Involving and improving parent participation at feeding rounds and educating them on the personalized feeding practices.

5. **Staff-centered feeding-related education:** Involved attempts to minimize variability and improve compliance, promote objective evidence-based practices, and discuss case studies and education at quarterly meetings and workshops.

The BPD-specific interventions adopted and personalized to clinical situation owing to heterogeneity were as follows: (1) monitor volume per feed with restriction of total volume up to 130 mL/kg per day, (2) monitor and minimize gavage feeding duration, (3) once a day oral feeding by occupational therapist to infants with CPAP and <30% FiO₂, (4) optimal feeding progression by optimizing dry weight twice weekly, (5) institutionalize use of length boards for
monitoring nutrition and growth, (6) restrict use of acid-suppressive medications to only after objective evaluation, and (7) restrict use of diuretics for patent ductus arteriosus (PDA) management. Infants with BPD have unique needs in terms of airway, pulmonary, nutrition, and interdisciplinary communication aimed toward implementation.

A series of multiple plan-do-study-act cycles were completed during our 3-month intensive training period (April 2010 to June 2010) before launching the SIMPLE feeding program. In addition, plan-do-study-act cycles were put in place for the entire duration of the project during the weekly rounds.

### Inclusion and Exclusion Criteria

All infants with a gestational age between 23 0/7 and 32 6/7 weeks with a postmenstrual age (PMA) at admission of ≥34 weeks and who were qualified or diagnosed to have BPD at 36 weeks’ PMA and discharged to home were included. Patients with the following conditions were excluded in this QI study because we could not follow aerodigestive milestones owing to the potential confounding nature of acuity-related changes in day-to-day management: death during admission; developed at least a grade-3 intraventricular hemorrhage; developed necrotizing enterocolitis (NEC) stage ≥3 (surgical); recurrent NEC of any stage; congenital, metabolic, or genetic anomalies; gastrointestinal anomalies; and any surgery (other than PDA), which includes neurosurgery, gastrointestinal surgery, and urological surgery. We excluded those infants who were transferred before full feeds because we could not follow further milestones.

### Statistical Analysis

The standard at our all-referral level IV NICU in the mid-Ohio region is to use the Institute for Healthcare Improvement model for improvement. All data were collected through review of patient electronic medical records. $\chi^2$ and $t$ tests were used to analyze categorical and continuous variables, respectively. Data analysis was performed by using SPSS version 21 (IBM Corp, Armonk, NY). Data are presented as $n$ (%) or mean ± SD. Box plots indicate median, 10%, 25%, 75%, and 90% ranges. The severity of BPD was classified on the basis of the National Institutes of Health consensus definition.

### Ethical Considerations

The study is determined as a QI project by our Institutional Review Board and was exempted from review.

### RESULTS

In Table 1, we show the comparison of the demographic characteristics and comorbidities between the baseline and SIMPLE feeding program group. Although the population characteristics were similar between the 2 groups, infants were referred to our tertiary center at a later PMA as compared with baseline. Proportions of
severity of BPD across the time period show that the overall prevalence of BPD has not increased ($P = .4$), but incidence of moderate (decreased) and severe (increased) BPD has changed ($P < .05$).

We further compared the feeding milestones in patients with BPD between the 2 groups (Fig 2). Full enteral feeds were reached on an average of 13 days sooner in the SIMPLE group compared with the baseline ($P < .001$); oral feeds were started sooner (by 11 days, $P = .02$) and thereby translated to the day of life when the full oral feeds also reached sooner in the program. Infants in the SIMPLE feeding program achieved all feeding milestones significantly earlier ($P < .05$).

Comparison of growth characteristics and discharge milestones is shown in Table 2. Duration of ventilation was higher and duration of CPAP was significantly lower in the SIMPLE feeding program (Table 2).

Length of stay (LOS) was significantly less in the SIMPLE feeding group as compared with the baseline, as shown in the control chart (Fig 3).

Readmissions within 1 month of discharge was used as a balancing measure and remained unchanged between the 2 groups.

**DISCUSSION**

In this report, we describe the impact of our established SIMPLE QI program among hospitalized premature infants with BPD, from admission to discharge. Ours is a tertiary care all-referral center; hence, admitted infants were at varying PMAs for varying problems with varying disease severity at inception, and, therefore, confounding variables could not be controlled. Our referral pattern has increased over the past few years to increasing catchment areas. Although in the SIMPLE group, the infants were admitted to our facility at a later PMA and had higher rates of severe BPD, our LOS was significantly shorter, even for this sicker population. Despite the higher severity of BPD, the growth parameters in this group were still comparable to baseline. Once infants qualified to have increased respiratory support needs, they were managed in a separate chronic-care BPD inpatient unit with a dedicated SIMPLE feeding (QI) program. BPD feeding rounds were conducted separately by common physicians from the feeding program and were different from regular BPD attending care providers.

Standardization of measures is viewed as a critical feature for consensus and collaboration among diverse stakeholder groups involved in the measurement of parameters, milestones development, and programmatic implementation.\(^7\) It is supported in the literature that QI projects focusing on implementing feeding guidelines in infants at risk for intestinal failure have helped to decrease the time to reach full enteral feeds by a median of 6 days ($P = .012$). In these studies, researchers have also focused on guideline development and adherence, multidisciplinary collaboration, and education, as done in our unit.\(^8\) Furthermore, our research group has shown that organized personalized feeding strategies involving both QI methods and therapeutic strategies among infants at risk for gastrostomy feeding has resulted not...
TABLE 2  Growth and Discharge Characteristics of BPD Infants

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Baseline, n = 83</th>
<th>SIMPLE, n = 135</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airway milestones</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of ventilation, d</td>
<td>25 ± 32</td>
<td>33 ± 31</td>
<td>.02</td>
</tr>
<tr>
<td>Duration of CPAP, d</td>
<td>31 ± 19</td>
<td>22 ± 21</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Growth milestones</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28 DOL wt, g</td>
<td>1131.2 ± 351.4</td>
<td>1242.4 ± 363.7</td>
<td>.02</td>
</tr>
<tr>
<td>36 wk PMA wt, g</td>
<td>2028.2 ± 316.6</td>
<td>2083.5 ± 411.3</td>
<td>.2</td>
</tr>
<tr>
<td>36 wk PMA length, cm</td>
<td>42.5 ± 3.1</td>
<td>42.3 ± 3.1</td>
<td>.9</td>
</tr>
<tr>
<td>36 wk PMA FOC, cm</td>
<td>30.4 ± 1.9</td>
<td>30.3 ± 1.9</td>
<td>.8</td>
</tr>
<tr>
<td>Discharge wt, g</td>
<td>3325.2 ± 945</td>
<td>3301.7 ± 1053.6</td>
<td>.5</td>
</tr>
<tr>
<td>Discharge length, cm</td>
<td>48.1 ± 4.7</td>
<td>48.3 ± 4.8</td>
<td>.1</td>
</tr>
<tr>
<td>Discharge FOC, cm</td>
<td>35.1 ± 2.9</td>
<td>34.2 ± 2.7</td>
<td>.03</td>
</tr>
<tr>
<td>Discharge milestones</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trach collar</td>
<td>2 (3)</td>
<td>0 (0)</td>
<td>.1</td>
</tr>
<tr>
<td>Gastrostomy tube</td>
<td>5 (8)</td>
<td>7 (5)</td>
<td>.5</td>
</tr>
<tr>
<td>Age at discharge, d</td>
<td>118 ± 47</td>
<td>109 ± 50</td>
<td>.1</td>
</tr>
<tr>
<td>PMA at discharge, wk</td>
<td>43 ± 6</td>
<td>42 ± 6</td>
<td>.2</td>
</tr>
<tr>
<td>LOS, d</td>
<td>107 ± 47</td>
<td>94 ± 49</td>
<td>.01</td>
</tr>
<tr>
<td>Readmission within 1 mo</td>
<td>13 (21)</td>
<td>17 (13)</td>
<td>.1</td>
</tr>
</tbody>
</table>

Data are presented as n (%) or mean ± SD. SIMPLE data were collected for 4 y versus baseline for 1 y before initiating QI program. DOL, day of life.

Only in improved feeding outcomes but were also associated with improvement in their Bayley developmental scores at 2 years. Thus, it is possible to apply the principles of the SIMPLE feeding strategy even in complex care settings where there is heterogeneity, such as in BPD. The single most common etiological factor for all illnesses is lack of focused and targeted education for all the stake holders. With this QI program, we address these issues, as described in Methods.

In this project, we have adapted several key elements of a successful QI project described in the literature, including, but not limited to, fostering teamwork, adherence to evidence-based guidelines crib-side teaching during well-organized feeding rounds, quarterly review of data on feeding milestones, and, more importantly, taking an approach of learning from every patient. In addition, our efforts were bolstered by the existence of a supportive institutional environment while operationalization of the measures, building a project-specific data collecting system, implementation of strategies to change clinician practice attitudes besides focusing on sustaining interdisciplinary leadership, and effective teamwork.

In a review by Pfister and Goldsmith, several QI collaborative efforts have been described with an aim to decrease BPD. Although BPD is predominantly a heterogeneous lung disease, it is suggested in evidence that optimal nutritional support is important for lung maturation and repair. Advanced applications in neonatal intensive care methods targeted to improve survival among premature infants may have resulted in higher morbidity rates (although not statistically significant from baseline), and one such critical morbidity is BPD and its severity states. The subset of BPD severity was further examined (Table 2, Figs 1 and Figs 2). Indeed, the severity profiles among the BPD population have changed significantly, and this may be due to multiple reasons. These reasons may include but are not limited to the following: increased severity of sickness at admission, resulting in transfer; later admission to the tertiary care unit and variability in intensive care processes before admission to our Nationwide Children’s Hospital NICU; continuing disease severity on admission; and, above all, the heterogeneity of BPD by definition of pathophysiology can be variable. The interventions targeted on the BPD population included early oro-motor stimulation, cautious advancement of enteral feeds despite the presence of PDA, and employing cautious oral feeding therapies while on nasal CPAP. Further research is needed to target the feeding strategies in modifying the BPD subtypes.

Further explanations for our outcomes and future considerations are highlighted below:

1. Admission to the tertiary care center, infants were sicker as evidenced by the need for prolonged ventilation (P < .05), although the duration of CPAP was lesser (P < .05). The respiratory disease severity profiles of the patients in the SIMPLE group are significantly different during the acute care (ventilation) or during the acute-chronic transition (CPAP). It is known from our previous work that the respiratory severity in the first month of life affects the long-term outcomes in patients with BPD. Specifically, for the purpose of the current study goals, opportunities to provide enteral feeding and oral feeding may be variable and delayed, owing to the aerodigestive support. Intensive cautious early feeding opportunities may be helpful in modifying the aerodigestive outcomes among the BPD patients. Although PDA rates are similar, surgical ligation in the SIMPLE group was lesser (P < .05). This may be due to accepting the consequences of medical PDA regardless of its hemodynamic significance. Whether this aspect of care has resulted in the increase in severity of BPD in this patient population cannot be answered by this study. Both severe BPD and surgical ligation of PDA are associated with long-term consequences. Larger studies are needed with adequate power to address this specific question. (3) LOS is reflective of multiple factors: preadmission factors, hospitalization factors, and peridischarge factors. Standardization of these factors to include greater attention to detail is needed, and constant education and support are needed to sustain and advance outcomes across the time period. This is particularly so because of changing patient demographics but also changing caregiver profiles, skill sets, and...
competency with feeding and breathing maintenance. To achieve a generalizable effect at any center, there is a need for focused programs, resources, passion, and perseverance to attain these definable aerodigestive milestones. Our SIMPLE feeding program approach offers a framework for such opportunities.

By the inherent nature of being a tertiary care facility, infants were referred to us at any point in their critical illness if they needed more-advanced care. Although we recognized this limitation, we had no control on the timing of admission at our NICU. Furthermore, there is also significant heterogeneity within the BPD disease, presence of comorbidities, and implementation of other aspects of holistic care that may have an impact on airway and digestive milestones. Although we started the SIMPLE QI program to improve feeding outcomes and decrease LOS, its only focus was not on BPD population alone. In this report, we specifically describe the BPD subset of patients.

However, our experience from this project and outcome of this work has resulted in specialized care of BPD populations on the basis of severity and heterogeneity. Since then, we have begun providing more-personalized service to patients with BPD within our comprehensive center of BPD.

LOS is often used as a complex outcome metric that is primarily affected by safe oral feeding or discharge feeding methods (gastrostomy needs) and can be modified by factors pertinent to patient-parent-provider factors and be affected by several QI endeavors in the NICU.9–12,28,29 In addition, in our study, we recognize that LOS may have been affected by several fixed and variable factors, which can be a limitation. When there are complex issues and multiple providers participating, the only way variability can be minimized is by education on specific issues on-site because no 2 conditions are alike. Despite all these limitations, we were able to influence the LOS to a significant extent by our SIMPLE program endeavors.

CONCLUSIONS

BPD infants were admitted at a later PMA in the SIMPLE program compared with the baseline period. Although overall BPD rates are similar, there were more infants with severe BPD in the SIMPLE feeding strategy group. Feeding milestones (full enteral feeds, first oral feed, and full oral feeds) were achieved significantly sooner in the SIMPLE group across all categories of BPD severity. Despite the severity of BPD and being admitted to our facility at a later PMA, our LOS is shorter even for this sicker population. SIMPLE feeding strategies support postnatal maturation and acquisition of feeding milestones, irrespective of the severity of BPD, and

![X-bar chart of the LOS of patients with BPD.](image_url)
decrease length of hospitalization, thereby lowering resource use.

The SIMPLE feeding strategy supported postnatal maturation and acquisition of feeding milestones, irrespective of the severity of BPD, and impacted the LOS, thereby lowering resource use. Tertiary care hospitals with high rates of BPD could benefit from a focused QI program to optimize feeding strategies in BPD patients. Earlier transfer to the referral hospital in infants that are likely to develop BPD may optimize growth and feeding milestones, reduce LOS, and perhaps modify the severity of BPD and therefore long-term outcomes. Minimizing the practice variability by standardization of several aspects of care during acute care, acute-chronic transition, chronic care, and postdischarge care of this BPD population is needed to improve outcomes globally.

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