RESEARCH ARTICLE

Increasing Immunization Rates in Infants with Severe Chronic Lung Disease: A Quality Improvement Initiative

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ABSTRACT

OBJECTIVES: Immunizations provide important protection from serious childhood illnesses. Infant chronic lung disease (CLD) is a serious complication of prematurity and predisposes premature infants to respiratory morbidity, rehospitalization, and mortality. This high-risk group is especially vulnerable to infections, such as invasive pneumococcal disease, influenza, and bronchiolitis. Our purpose for this project was to increase 2-, 4-, and 6-month immunization rates in eligible infants with CLD in the NICU by 30% through December 2016.

METHODS: A multidisciplinary team developed weekly targeted rounds to identify eligible patients with outstanding immunizations. Exclusion criteria included the following: (1) a fraction of inspired oxygen requirement of >80%, (2) pulmonary hypertensive crisis, (3) positive blood culture results or if within 48 hours of a sepsis evaluation, (4) if within 5 days of a surgical or interventional procedure, (5) receiving steroid treatment (not including a physiologic hydrocortisone dose for adrenal insufficiency), (6) a CLD team consensus of contraindication, and (7) parental refusal.

RESULTS: The project managed 60 patients from March 2016 to December 2016. Immunization of eligible patients increased from 44% to 75% and was sustained for the next 6 months. The average number of days from admission to immunization record review decreased from 71 days at baseline to 27 days.

CONCLUSIONS: The implementation of (1) an in-hospital immunization record review, (2) an e-mail reminder, (3) a weekly multidisciplinary eligibility discussion, and (4) an updated rounding tool was successful in increasing and sustaining immunization rates in this population of infants with CLD. The multidisciplinary CLD meeting was a novel opportunity to discuss immunization eligibility and safety monitoring.

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Immunizations provide important protection from serious childhood illnesses. According to a report from the Centers for Disease Control and Prevention in 2014, immunizations could prevent ~21 million hospitalizations and 732 000 early deaths in children across the United States over a 20-year period. As such, immunization is 1 of the most effective of all public health interventions. Infant chronic lung disease (CLD), also called bronchopulmonary dysplasia (BPD), is a serious complication of prematurity and predisposes premature infants to respiratory morbidity, rehospitalization, and mortality.[1] This high-risk group is especially vulnerable to infections, such as invasive pneumococcal disease, influenza, and bronchiolitis. A majority of readmissions are secondary to respiratory disorders, particularly respiratory syncytial virus and lower respiratory tract infections.[2] Such rehospitalization of premature infants, specifically those <25 weeks' gestational age, incurs higher health care costs during their first year of life.[1] Hence, adherence to proper immunization schedules is key to preventing morbidity and rehospitalization in these infants.

Hospitalization is an opportune time to assess immunization status and ensure up-to-date immunizations.[3,4] In this setting, a reliable review process of the patient's immunization record can decrease the risk of missed immunization opportunities and allow providers to answer parent's questions on the benefits, risks, and safety of immunizations. Preterm infants with severe CLD are often severely ill and require respiratory support and prolonged hospitalization in the NICU during a time that often overlaps with the American Academy of Pediatrics immunization opportunity windows. However, the potential risk for clinical decompensation after immunization in premature infants who are critically ill is a considerable factor for immunization postponement. Clinicians often delay immunizations in patients with CLD over concerns about clinical instability related to their CLD as well as the potential side effects of the immunizations. Some studies suggest that immunization has been associated with an increased risk of sepsis evaluations, a need for increased respiratory support, and unplanned intubation in infants with very low birth weight.[5] However, 1 study revealed that preterm infants who received the diphtheria-tetanus-acellular pertussis vaccine at 2 months after birth are no more likely to experience prolonged apnea and bradycardia than control infants.[6] Another retrospective cohort study of premature infants <32 weeks' gestational age revealed that respiratory decompensation requiring clinical intervention after immunizations in infants with BPD is uncommon and comparable with that in infants without BPD.[7]

The quaternary neonatal/infant ICU (N/IICU) at an urban, academic quaternary-care facility in the mid-Atlantic region is home to the CLD program. The program cares for 50 to 70 infants with severe CLD per year. From 2014 to 2016, various regional and international centers referred 179 patients to the CLD program, with 61% of patients from within the state and 39% of patients were from other states and international. These infants arrived at a median chronological age of 86 days and had a median length of stay of 100 days. Thus, the majority of them were eligible for immunizations at least once during their hospitalization. A chart review of patients cared for by the CLD team revealed that in 2014–2015 only 32% of patients (n = 65) were up to date with immunizations at 2, 4, or 6 months. Delays by >30 days for at least 1 immunization were found in 59% of the delayed group.

Quality improvement (QI) methodology has revealed effectiveness in applying recommended standards of care in other settings, such as hand-washing and infection prevention. This methodology inspired us to begin the initiative to improve immunization rates in this CLD group. During 2016–2017, the CLD team aimed to increase immunization compliance in accordance with the Centers for Disease Control and Prevention guidelines and avoid missed opportunities during hospitalization. The objective was to increase 2-, 4-, and 6-month immunization rates in eligible infants with CLD in the NICU by 30% through December 2016. Immunizations tracked at these 3 time points were those recommended by the American Academy of Pediatrics, including one for rotavirus.

METHODS

This project spanned from February 2016 to December 2016 in the 98-bed N/IICU at a freestanding, urban, and academic quaternary-care hospital. The project team consisted of frontline clinicians from the CLD team, key stakeholders, and an improvement advisor coach. The patients included in the study were premature infants with severe CLD (based on *Eunice Kennedy Shriver* National Institute of Child Health and Human Development criteria) who were eligible for 2-, 4-, or 6-month immunizations.[8] For patients on nasal cannula, we included those with a high-flow nasal cannula rate of >3 L per minute and categorized them as having severe BPD.

The team created a diagram of key drivers that would be used to ensure proper adherence to the immunization of infants with CLD, including increasing immunization awareness, optimizing time for immunization administration, improving immunization documentation, and providing patient safety evaluation (Fig 1).

With the unique nature of patients with CLD and repeated clinician concerns (whether real, perceived, or unknown) for clinical instability after immunization, it was necessary to agree on a set of exclusion criteria for allowing immunization delay in this population (infants not eligible for immunization during the scheduled time). Via consensus, attending neonatologists on the CLD team established the following exclusion criteria: (1) a fraction of inspired oxygen (FIO_2) requirement of >80%, (2) pulmonary hypertensive crisis, (3) positive blood culture results or if within 48 hours of a sepsis evaluation, (4) if within 5 days of a surgical or interventional procedure, (5) receiving steroid treatment (not including a physiologic hydrocortisone dose for adrenal insufficiency), (6) a CLD team consensus of contraindication, and (7) parental refusal. Each week, during team rounds, the CLD team discussed the eligibility for immunization of each CLD patient according to these predefined criteria.

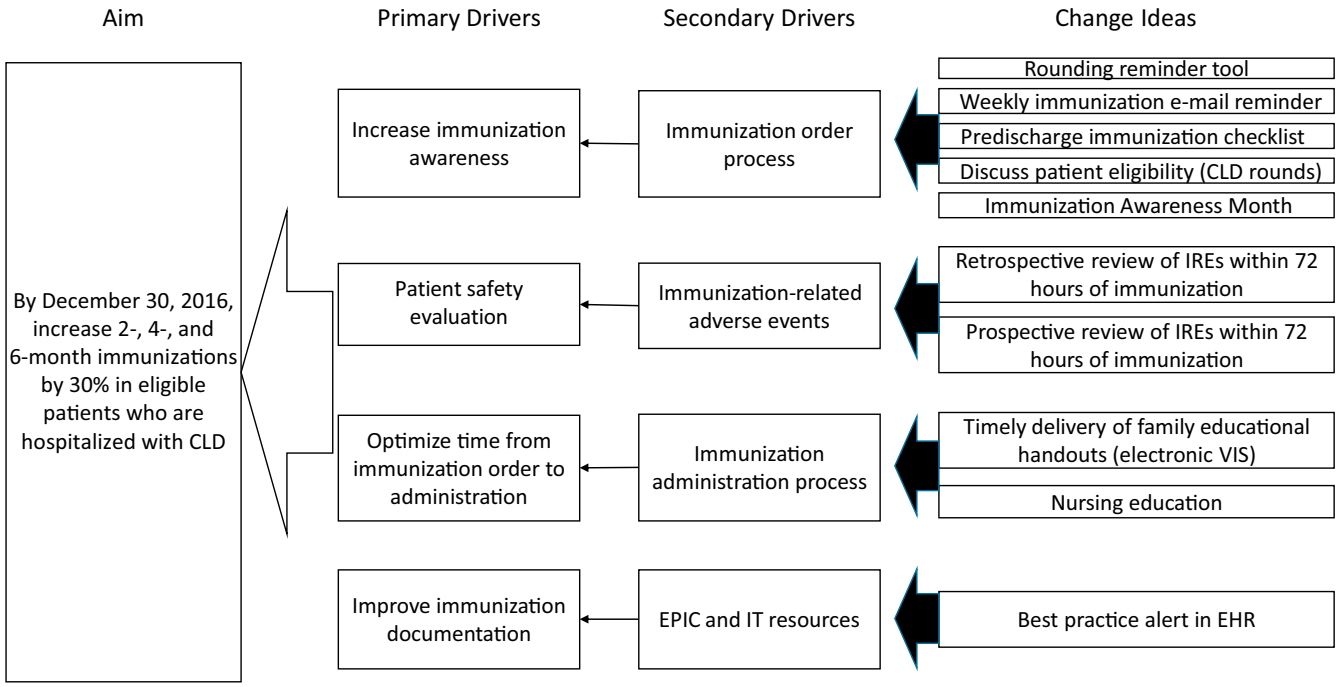

FIGURE 1 Driver diagram. EHR, electronic health record; EPIC, EPIC electronic health records; IT, information technology; VIS, vaccine information statement.

Outcome metrics were reported biweekly and included the percentage of eligible patients immunized and the number of days since the last missed immunization opportunity. Patients were defined as eligible if they had due or upcoming immunizations within 7 days. A missed immunization opportunity was defined as when an eligible patient had a >14-day delay from their immunization due date. Process metrics were days since the last missed patient eligibility discussion during CLD rounds, hours from immunization order to administration, and number of days between admission to immunization record review by the provider. Baseline data for immunization rates were collected prospectively during February 2016 and confirmed by performing a chart review obtained from a sample of hospitalization records of patients with CLD from 2014 to 2015. Prospectively, we followed our outcome metric biweekly from February 2016 to December 2016.

Starting in June 2016, after reaching a consensus among CLD team members, we tracked clinically significant immunization-related events (IREs) that were presented within 72 hours after immunization administration. By using the same definitions, a retrospective chart review of IREs was conducted from a sample of infants with CLD from August 2013 to October 2015. We grouped IREs into 3 categories on the basis of potential for clinical decompensation: (1) mild events, such as fever; (2) moderate events, such as a sepsis evaluation or blood culture results negative for sepsis; and (3) severe events, such as blood culture results positive for sepsis, unplanned intubation, increased respiratory support, or pulmonary hypertensive crisis. A fever was defined as an axillary temperature of >38°C. A sepsis evaluation was defined as starting patients on antibiotics because of clinical decompensation or laboratory abnormalities but discontinuing at 48 hours if blood culture results were negative. A blood culture result negative for sepsis was identified if patients received an antibiotic treatment course of >48 hours despite negative blood culture results. Conversely, a blood culture result positive for sepsis was identified if there were positive blood culture results. Increased ventilatory support was defined as an increase of >20% in ≥1 of 3 baseline ventilatory settings (positive inspiratory pressure, respiratory rate, or inspired oxygen fraction). Pulmonary hypertensive crisis was defined as when nitric oxide was either initiated or increased by 20%, determined by comparing the highest value 48 hours before immunization and the highest value within the 72 hours after immunization.

The team identified key drivers and tested several change ideas, focusing particularly on interventions to improve the immunization order process. These changes included the following: (1) a weekly patient eligibility discussion during CLD team rounds, (2) a weekly e-mail reminder to the clinical team listing all patients with due or upcoming immunizations, (3) adding a clinical care question ("Are immunizations up to date?") to the existing patient rounds reminder tool, (4) a revised predischarge immunization checklist, and (5) observing an Immunization Awareness Month. The team planned, executed, analyzed, and implemented these changes using several plan-do-study-act cycle ramps. In addition, we targeted the immunization

administration process through nursing education.

We used the science of improvement methodology to guide the design of this project, with mentoring from the Institute for Healthcare Improvement (IHI) advisor program. Metrics were visualized on run charts and Shewhart control charts to understand variation and identify special causes.[9] Special cause was determined by 6 consecutive points on either side of the centerline. We used the software QI macros and identified special cause variation using the IHI rules. This QI project received institutional review board exemption.

RESULTS

Our baseline data from February 2016 was consistent with the low immunization rates found in a retrospective review of patients from 2014 to 2015. Between March 2016 and December 2016, 60 infants met inclusion criteria and were managed during the study period. These infants had a median chronological age on admission of 97 days and a median length of stay of 91 days. At baseline (48 hours before immunization), 60% ($n = 39$) of patients were on invasive mechanical ventilation, with an average F_{IO_2} of 41% (22%–79%) and a mean airway pressure of 17 cm H_2O (8–38 cm H_2O), and 38% ($n = 15$) of patients were on inhaled nitric oxide.

On average pre-week and within a stable system for the duration of the project, 57% ($n = 3$) of eligible patients had a reason for postponing 2-, 4-, or 6-month immunizations according to the CLD team weekly discussion. Patients were deferred because (1) the patient was critically ill or unstable (pulmonary hypertensive crisis, F_{IO_2} of >80%, or team consensus), (2) it was within 5 days of an operation or interventional procedure, or (3) there were concerns for sepsis.

Since June 2016, the percent of eligible patients who were immunized increased from a median of 44% to 75%, revealing special cause variation (a shift of 6 points above the median). This improvement was sustained for the next 6 months (Fig 2). To avoid missing a patient discussion, CLD rounds were rescheduled if a meeting did not take place. A second nurse was trained to lead CLD rounds, and we followed-up with the team regarding the patient's immunization plan. The CLD team did not miss a patient eligibility discussion in 144 days. By the end of the project, the number of days since the last missed patient immunization was 242 days.

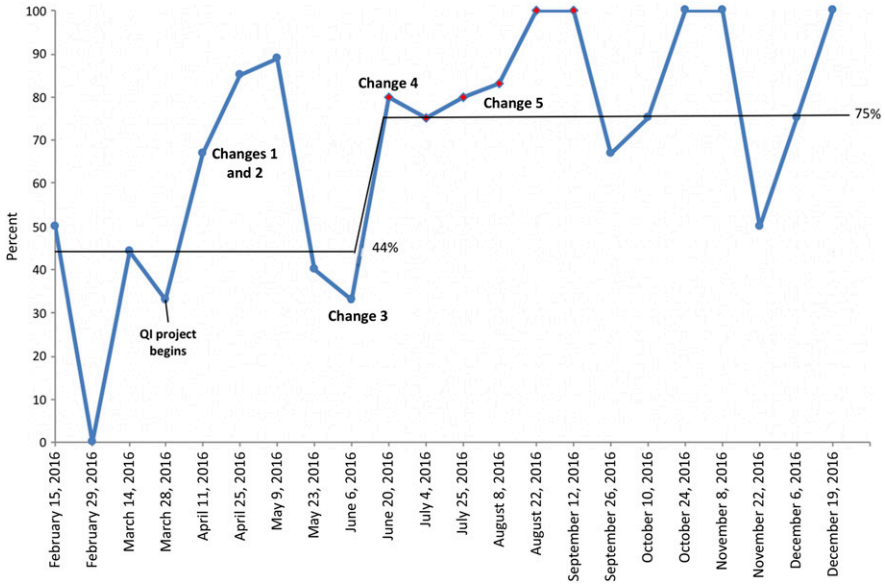

FIGURE 2 Percentage of eligible patients immunized bimonthly (run chart). The following changes are documented: change 1, immunization eligibility discussed on weekly CLD rounds; change 2, weekly immunization e-mail reminder; change 3, weekly immunization rounding tool; change 4, predischarge immunization checklist; and change 5, Immunization Awareness Month.

The average number of days from admission to immunization record review decreased from 71 days at baseline to 27 days (Fig 3). The greatest impact was identified during and immediately after Immunization Awareness Month (see change 5 in Fig 3). In the subsequent months, there was an upward trend within a stable system. The number of hours from immunization order to administration decreased from 38 to 15 hours, occurring after Immunization Awareness Month, but it was not sustained in the following months.

According to a chart review, 43% ($n = 15$) of infants with severe CLD ($n = 35$) who were immunized between August 2013 and December 2015 presented with an IRE. To monitor patient safety as immunization rates increased, we tracked IREs since July 2016. Of 30 immunization events, 44% ($n = 13$) of patients presented with an IRE within 72 hours of immunization, which was similar to an IRE rate of 43% at baseline. Of all IREs presented within both time periods, 53% ($n = 20$) were categorized as mild, 26% ($n = 10$) were categorized as moderate, and 21% ($n = 8$) were categorized as severe. Severe IREs during the QI project included 2 blood cultures positive for sepsis, 1 unplanned intubation, and 1 pulmonary hypertensive crisis. There were no deaths associated with immunization.

DISCUSSION

The implementation of (1) an in-hospital immunization record review; (2) an e-mail reminder; and (3) a weekly multidisciplinary eligibility discussion was successful in increasing and sustaining immunization rates in this population of infants with CLD. The multidisciplinary CLD meeting was an optimal environment to discuss immunization eligibility and provided a novel opportunity for discussion and safety monitoring.

During hospitalization, the patient's immunization status is usually verified on the basis of parental recall. One study revealed that inhospital immunization

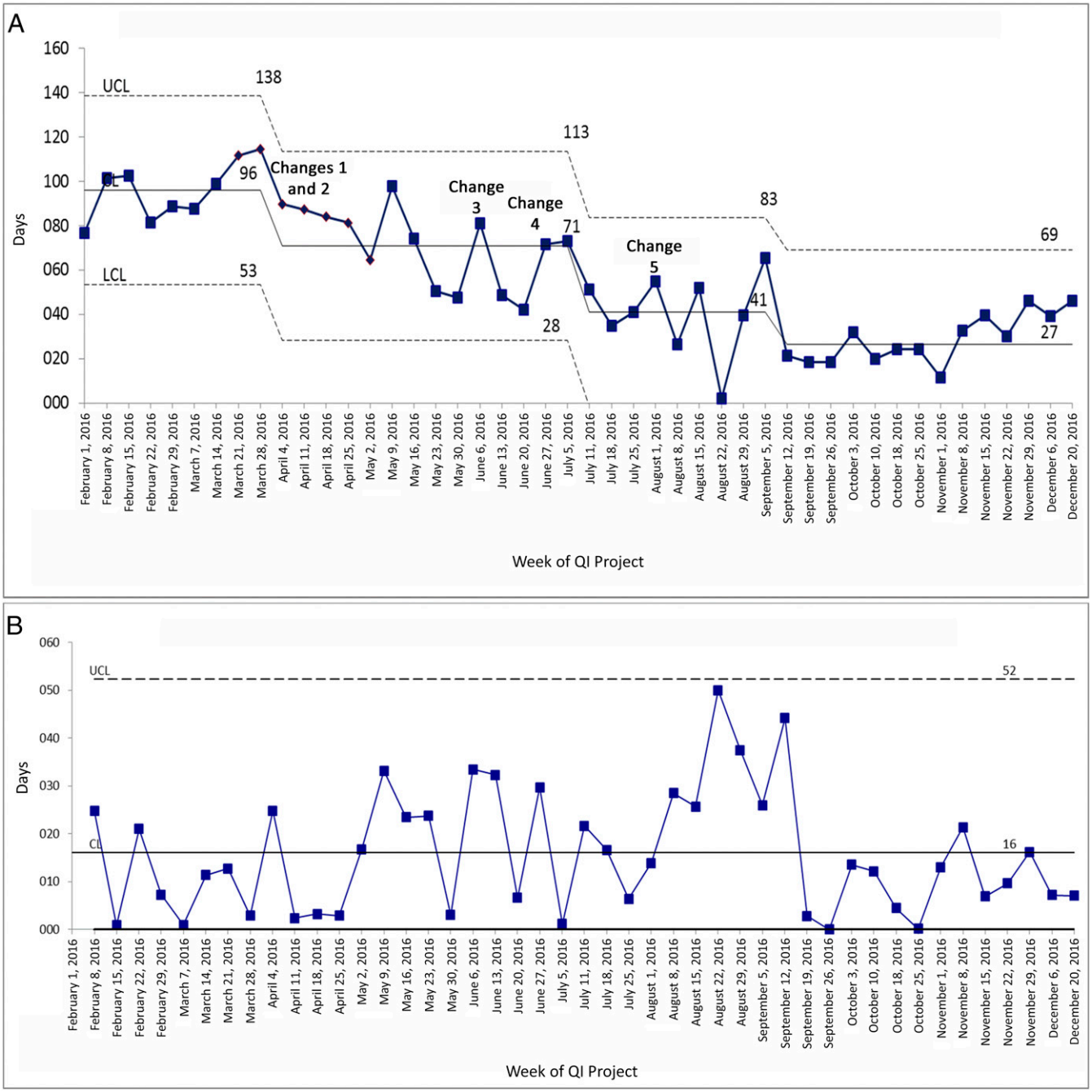

FIGURE 3 Average days from admission to immunization record review per week (X-bar and S charts). The following changes are documented: change 1, immunization eligibility discussed on weekly CLD rounds; change 2, weekly immunization e-mail reminder; change 3, weekly immunization rounding tool; change 4, predischarge immunization checklist; and change 5, immunization awareness month. A, Average days from admission to immunization record review per week (X-bar chart). B, Average days from admission to immunization record review per week (S chart). CL, control line; LCL, lower control limit; UCL, upper control limit.

documentation based on parental recall may not represent actual compliance to immunization schedules.[10] In this regard, authors of some studies have established the importance of reviewing the patient's immunization record during hospitalization when the patient is admitted.[1] We observed an important improvement in the average number of days it took for the frontline provider to review the patient's immunization record after admission to the hospital. We believe it played an important role in maintaining an up-to-date immunization record during the patient's hospitalization.

Concern for potential clinical instability after receiving immunizations was an obstacle to timely immunization, especially in this unique and fragile CLD population. Clinician participation in the development of exclusion criteria successfully resulted in clinician engagement. Providing additional layers of awareness, such as e-mail reminders and audits, increased routine review and awareness of patients' immunization status, thereby driving thoughtful multidisciplinary discussion during CLD rounds every week. Additionally, enterprise-wide immunization initiatives, such as an Immunization Awareness Month, emphasized institutional support for this work. Not surprisingly, we found repetition to be necessary for sustainable improvement.

Key lessons learned included the importance of an effective reminder system that could be integrated well into the existing clinician workflow and the dedication of a multidisciplinary clinical team of providers, nurses, and staff who can consistently engage their peers in this work. The implementation team was able to adapt their intervention with deference to frontline opinions about immunization deferral. Therefore, there is potential for spreading this framework to other groups of patients with chronic conditions that present similar immunization challenges.

We noted some variation in the system after change 5 took place (Fig 2). We believe that holding the gains after an improvement takes place is part of most improvement initiatives, is a challenging issue, and should be addressed by using QI methodology. In this QI project, we focused on 2-, 4-, and 6-month immunizations and excluded influenza immunization and palivizumab administration. Inclusion of such opportunities is underway. Although we can show associations between immunization administration and IREs, we cannot conclude causality. Additionally, we cannot determine which change specifically impacted our results because of the few time points between interventions. Finally, there may be confounding variables embedded in the practice of clustering immunization administration versus separating it over a few days. Such important questions should be studied under research protocols.

Since implementation, immunization and immunization record review rates are now reported monthly during quality assessment performance improvement meetings, and immunization eligibility discussion has become integrated in the weekly CLD rounds discussion. In addition, the clinical immunization care question is used on a weekly basis in CLD team bedside rounds to continue to enhance immunization awareness.

To sustain improvement gains, next steps include the implementation of best practice alerts in the electronic health record, which would eventually replace the weekly e-mail reminder, as well as the deployment of telemedicine and online tools to educate families earlier in the hospital course, thereby reducing parental consent wait times. These 2 interventions are currently being developed and implemented in the NICU. Finally, a mechanism to better track and report IREs remains important to monitor patient safety.

CONCLUSIONS

Timely immunization to avoid immunization-preventable illness is important to ensure overall health and avoid further lung injury in infants with CLD. We were able to increase immunization rates in this patient population without increasing IREs. This project reveals that despite the concerns for clinical instability, immunizations can be given safely for most infants with severe CLD through careful planning.

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