Electronic Alerts Improve Immunization Rates in Two-month-old Premature Infants Hospitalized in the Neonatal Intensive Care Unit

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Keywords

alerting, clinical information systems, electronic health records and systems, neonatology, requirements analysis and design

Summary

Objective: To determine if an electronic alert improves 2 month immunization rates in infants remaining hospitalized in the neonatal intensive care unit.

Methods: Institutional Review Board-approved retrospective chart review of 261 infants with birth weights <2 kg and still hospitalized at ≥ 58 days. Charts were reviewed between 2009 and 2013, before and after the 2011 electronic alert was instituted in the electronic medical record from days 56 to 67 to remind providers that immunizations were due. Order and administration dates of two-month vaccine components (Diphtheria, Haemophilus influenza B, Hepatitis B, Pertussis, Pneumococcal, Polio, Tetanus) were determined, and infants were considered fully immunized, partially immunized, or unimmunized by day 90 or discharge, whichever came first.

Results: After the alert, the timing of vaccine orders decreased from day 67 to day 61 ($p<0.0001$) and vaccine administration decreased from day 71 to day 64 ($p<0.0001$). Missing vaccine orders decreased from 14% [17/121] to 3% [4/140] ($p=0.001$) with missing administrations decreasing from 21% [26/121] to 4% [6/140] ($p<0.0001$). Fully immunized rates increased from 71% [86/121] to 94% [132/140] ($p<0.0001$).

Conclusions: A significant improvement in immunization rates in two-month-old infants in the neonatal intensive care unit occurred by 90 days after implementing an alert in the electronic medical record.

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1. Background and Significance

Infants are admitted to the neonatal intensive care unit (NICU) for a variety of medical diagnoses, the most common being prematurity. In 2003, the American Academy of Pediatrics recommended that medically stable premature infants receive recommended vaccines at the same chronologic age as full term infants [1]. While many premature infants are still hospitalized at two months of age, they are often in a fairly healthy state awaiting physiologic maturity before safe discharge can occur. These premature infants may not receive timely immunizations due to healthcare providers focusing on the therapies these infants need for treatment, leaving preventative needs overlooked [1, 2].

Studies have shown that low birth weight infants have approximately 15% lower immunization rates in the first six months of life compared to normal birth weight infants [2, 3]. For infants born at less than 1000 grams, their immunization rates were 33% lower than normal birth weight infants [3]. When vaccines are missed or delayed, especially in preterm infants who are already more susceptible to infection than their term peers, these infants are vulnerable to preventable diseases that can be deadly. Furthermore, these children are at risk of a domino effect if catch-up adjustments in future vaccines are not undertaken [4]. Batra (2009) showed this effect in extremely low birth weight infants lagging behind their normal birth weight peers at twelve months of age [3].

Technology has rapidly infused into clinician workflows in areas demanding high performance, such as the intensive care unit. Less than 10 years ago, the majority of hospitals lacked the capability of computerized provider order entry (CPOE) [5]. With CPOE came the potential for error reduction with the ability to provide clinician feedback for drug interactions and medication prescribing errors. As the systems gained more widespread use, it was determined that the unintended consequences of these technologies included poor compliance, alert overrides, workflow interruptions, and other types of errors [6, 7]. Up to 96% of alerts are ignored with studies showing feedback given closer to the moment of action had more impact [8, 9].

Electronic immunization reminders have been shown to improve timely immunization rates of children in ambulatory pediatric offices as well as adults at the time of hospital discharge [10, 11]. Influenza immunization rates in hospitalized children rose following screening using a nursing-based tool in the electronic medical record (EMR) [12]; therefore, it was suspected that an immunization reminder for the NICU population would improve appropriate immunization rates in this population as well. We were unable to find published results on the effect of an electronic medical record immunization alert in our population, so we decided to look at the effects that our immunization alert provided when implemented in 2011.

2. Objective

This retrospective study was designed to determine if an electronic immunization alert improved appropriate immunization status by 90 days of age in two-month-old infants remaining hospitalized in the NICU.

3. Methods

3.1. Subjects

All infants with birth weights of less than 2 kg who were admitted to the Level IV NICU at the University of Oklahoma Children's Hospital between 2009–2013 were included if they remained hospitalized until at least 58 days of age. Infants were excluded if they were transferred into the NICU after 50 days of age due to the need to ensure stability prior to immunization administration or if their immunizations were due between 30 days before the alert and 30 days after the alert to ensure clean data collection between the two alert periods.

3.2 Alert Description

In 2011, an electronic alert was developed to remind providers that immunizations were due. For clinicians, the pop-up alert was activated upon accessing a patient's record for the first time during a date that matched the alert date criteria. For nurses, the alert only appeared for initial patient record access between 0600 and 1200 so that nurses could prompt clinicians during rounds for immunization orders and to limit alert fatigue. The alert started at 56 days of age and ended after 67 days of age. It continued for each individual user until either immunizations were documented, the user clicked on a button marked "Immunizations ordered. No need to remind me again." or the immunization alert stop date was reached. The length of the alert was arbitrarily chosen to limit alert fatigue based on typical clinical practice.

3.3. Chart Review and Methods

The study was approved by the University of Oklahoma Health Sciences Center Institutional Review Board. The author / EMR administrator conducted a retrospective chart review of hospital medication orders and vaccine administration records between 2009–2013. Vaccines were ordered and administration documented through medication scanning in an electronic ordering system separate from the EMR. Vaccine administration was also documented manually by nurses in the immunizations section of the EMR which is automatically transferred to the clinican's discharge summary. To account for short periods when multicomponent vaccines may have been unavailable, records were searched for the dates that all routine two month vaccine *components* (Diphtheria, Haemophilus influenza B, Hepatitis B, Pertussis, Pneumococcal, Polio, Tetanus) were ordered and administered. Due to the live nature of Rotavirus vaccines, we do not administer it to hospitalized infants, and thus, it was not included. Nursing and clinician progress notes were also searched for parental refusal of vaccination and documentation of the need to delay vaccines due to medical instability.

Infants were considered "fully immunized" if they received all vaccine components, "partially immunized" if they received at least 1 but not all components, or "unimmunized" if they received none of the components by day 90 or the day of discharge, whichever came first. Any delay beyond this time impedes four-month immunization completion by 120 days of age using the four-week interval catch-up schedule.

3.4 Statistical Methods

The statistical analyses were completed using GraphPad Instat, version 3.0 (GraphPad Software, San Diego, CA; www.GraphPad.com) with two-tailed significance defined with an alpha of 0.05. Demographics and vaccine order and administration days were reported as mean (25^{th} percentile, 75^{th} percentile) and compared using Mann-Whitney U tests due to unequal standard deviations. The categorical outcomes of immunization status as well as missing vaccine orders and administrations were reported as a numerator/denominator (percentage) and were calculated using the Fisher's Exact test.

4. Results

Two hundred sixty-one infants met inclusion criteria, 121 pre-alert (2009–2011) and 140 post-alert (2011-2013). Of the unimmunized infants, six were documented as vaccine refusal (4 pre-alert, 2 post-alert) but were included as intent-to-treat subjects. Seventeen infants in the pre-alert group and 4 infants in the post-alert group were removed from the analysis of vaccine order day because they did not have vaccines ordered. Likewise, an additional 9 infants in the pre-alert group and 2 infants in the post-alert group who had orders but did not have vaccines administered were removed from the calculation of vaccine administration day.

Our results (shown in ▶Table 1) include demographic data, vaccine order and administration day, and final immunization status by day 90 for infants in the pre-alert versus post-alert periods.

Our results show that the vaccines were ordered 6 days sooner and administered 7 days earlier in the post-alert versus pre-alert phase ($p<0.0001$). There was also a 23% increase in the number of infants who were fully immunized at 90 days of age or discharge, whichever occurred earlier ($p<0.0001$). After the alert, the percentage of infants missing vaccine orders decreased by 11% ($p=0.001$) while those missing vaccine administrations decreased by 17% ($p<0.0001$).

5. Discussion

This study shows that immunization alerts in an EMR significantly improve two-month immunization rates in infants hospitalized in the NICU. Other studies have found NICU immunization rates at discharge to be between 51% [13] and 74% [14] which is similar to our baseline of 71%. Our findings show that the two-month immunization rate at the time of hospital discharge increased to 94% after the electronic immunization alert was implemented. Vaccines were ordered and administered a week earlier and there were 11% fewer infants missing vaccine orders after the alert was instituted. To our knowledge, this is the first study to report the effect an electronic immunization alert has on this inpatient critical care population.

There are many barriers to immunization administration in the NICU, including medical, social, and procedural factors. Despite the alert, we continued to have 3% of our infants missing vaccine orders. There will always be infants in the NICU who are deemed too unstable or have a medical condition that will not allow administration of vaccines in a timely manner. A limitation of our study is that we often did not find explanatory documentation for the non-administration of timely vaccines which may have included lack of parental consent, inability to acquire a specific vaccine, or contraindication to vaccine administration. Incomplete documentation is ubiquitous to retrospective chart reviews such as ours. It is possible that pre-alert infants were more unstable and the lack of documentation did not allow us to exclude this as a reason for our findings. However, from our clinical experience of increasingly premature and sicker infants being admitted to our NICU, it is unlikely that this would have affected the pre-alert timeframe more than the post-alert one. Realistically, we will never be able to reach 100% vaccination rates as long as elective parental refusal remains an issue. Different areas of the United States will likely have differing goals for vaccination status based on the populations they serve.

It is important to realize that the ordering of vaccines does not ensure that infants will actually receive the immunizations. In our current environment of national shortages, our hospital has experienced intermittent vaccine unavailability. This has led to providers having to order the vaccine components separately instead of the routine combination vaccines that are set up in our electronic order sets. To account for this limitation in our study, we documented vaccine components rather than specific immunizations. We noted errors in the ordering of single vaccine components in the forms of both duplication as well as missing orders for one or more components which strengthens the need for standardized order sets. These sets should be modifiable by the pharmacy when there are shortages to ensure ordering errors are minimized. We also found instances in which the vaccines were ordered and nursing personnel documented delaying administration "until tomorrow" which resulted in overlooked administration. Nursing documentation stated in one case that vaccines were found in the refrigerator after the infant's discharge.

We propose that EMR vendors recognize that the alerts should be continued until all vaccine components (or a non-administration reason) are documented in order to disable the alert. While having an alert fire every day after a reasonable alert period may cause alert fatigue, it might be reasonable to have the alert continue on a less frequent (weekly) basis. It would be helpful for EMR vendors to enable administrator modifications of reminders so they can be adapted to the facility-specific required documentation needs. Additional options should be available, such as: 1) refused, 2) inappropriate for clinical condition, 3) vaccine unavailable, 4) contraindicated, 5) parents desire to wait until follow-up appointment, or 6) other (with a text box for further documentation). These options can help identify areas for improvement and also indicate that the missing vaccines are not due to missed opportunity. Automatic vaccine registry integration through interface development is likely to enhance documentation as well as save time for current and future healthcare providers.

Lot-tracking through the use of barcoding in the EMR could provide the means for adverse event notification and automated pharmacy order fulfillment [15].

Several methods exist that could increase the immunization rate of NICU infants, including integrating medication administration systems with the EMRs so that vaccines are automatically documented when scanned, options for clinicians when the alert appears to allow for on-the-spot immunization ordering, and integrating consent forms and vaccine information statements into the EMR. We likely saw an improvement in missing vaccine administrations after the order alert because of the integration of our EMR system in which nurses are alerted in addition to the clinicians. Adding an additional layer, such as pharmacists who might receive an alert only in cases of non-administration within a defined period of time, might improve compliance. In cases of under-immunization, it would be helpful to have an additional prompt at the time of discharge to alert the provider to the immunization status and reason so that an additional attempt can be made to provide catch-up vaccines. Weekly automated reports of under-immunized inpatients sent to quality officers and quality metric dashboards might provide transparency in the process. Furthermore, The Joint Commission's Quality Measures are currently lacking in neonatal-relative items; appropriate immunization status at the time of hospital discharge should be considered as a Joint Commission Quality Measure to enhance surveillance of this outcome.

6. Conclusions

A significant improvement in appropriate immunization rates and timing of administration in two-month-old infants in the NICU occurred after implementing an immunization alert in the EMR. Integrating electronic systems for ordering, administration, documentation, and national reporting of immunizations should be the goal. Because it is possible that immunization-deficiency may increase the number of inpatient or emergency room visits for unimmunized children, future studies should include a detailed look at the outcomes of missing or delayed immunizations by identifying the reasons for readmissions and/or emergency room visits in comparison to immunization status in former premature infants.

Abbreviations/Acronyms

- CPOE: computerized provider order entry
- EMR: electronic medical record
- NICU: neonatal intensive care unit

Question

Implementing an immunization pop-up alert in an electronic medical record system results in which of the following?

A Higher rates of unimmunized infants in the neonatal ICU
B Longer elapsed time from vaccine order to administration
C Higher rates of fully immunized infants discharged from the neonatal ICU
D Shorter length of hospital stay

The correct answer is C. Implementing an immunization alert in an electronic medical record system resulted in a 23% increase in the number of neonatal ICU infants who were fully immunized at 90 days of age or discharge, whichever came earlier. The number of unimmunized infants decreased from 17% to 4% when the alert was implemented. The alert did not affect the length of hospital stay or the time from the vaccine being ordered until it was administered although infants completed the vaccine series approximately one week sooner.

Clinical Relevance

This study demonstrates that an immunization alert in the EMR significantly improves immunization rates and timing of administration in two-month-old infants who are still inpatient in the NICU. Infants were more likely to be fully immunized upon discharge from the NICU when the EMR alerted the clinician during the hospitalization.

Conflict of Interest

The author has no conflict of interest to disclose.

Human Subjects Protections

This study was performed in compliance with the Institutional Review Board standards for privacy and confidentiality. No direct contact was made with animal or human subjects.

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Table 1 Timing of Vaccines and Immunization Status in the Neonatal ICU at 90 Days or Discharge

	Pre-Immunization Alert[a]	Post-Immunization Alert[a]	p-values
Demographics			
Total Infants	121	140	
Birth Weight (grams)	984 (771, 1170)	933 (730, 1033)	0.19[b]
Length of Hospitalization (days)	87 (64, 98)	92 (69, 105)	0.08[b]
Vaccine Data			
Number of Infants Missing Vaccine Orders	17/121 (14%)	4/140 (3%)	0.001[c]
Day Vaccine Ordered (day of life)[d]	67 (60, 69)	61 (59, 62)	<0.0001[b]
Number of Infants Missing Vaccine Administration	26/121 (21%)	6/140 (4%)	<0.0001[c]
Day Vaccine Administered (day of life)[e]	71 (62, 74)	64 (60, 64)	<0.0001[b]
Immunization Status at 90 Days or Discharge[f]			
Fully Immunized	86 (71%)	132 (94%)	<0.0001[c]
Partially Immunized	14 (12%)	2 (2%)	0.001[c]
Unimmunized	21 (17%)	6 (4%)	<0.001[c]

[a]Mean (25th percentile, 75th percentile)
[b]Mann-Whitney U Test
[c]Fisher's Exact Test
[d]Only includes infants with orders available (n=104 pre-alert, n=136 post-alert)
[e]Only includes infants with all vaccines administered (n=95 pre-alert, n=134 post-alert)
[f]Fully Immunized = all vaccines administered; Partially = at least 1 but not all vaccines administered; Unimmunized = no vaccines administered

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