Effect of Electronic Health Record Reminders for Routine Immunizations and Immunizations Needed for Chronic Medical Conditions

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Abstract

Background Immunization reminders in electronic health records (EHR) provide clinical decision support (CDS) that can reduce missed immunization opportunities. Little is known about using CDS rules from a regional immunization information system (IIS) to power local EHR immunization reminders.

Objective This study aimed to assess the impact of EHR reminders using regional IIS CDS-provided rules on receipt of immunizations in a low-income, urban population for both routine immunizations and those recommended for patients with chronic medical conditions (CMCs).

Methods We built an EHR-based immunization reminder using the open-source resource used by the New York City IIS in which we overlaid logic regarding immunizations needed for CMCs. Using a randomized cluster-cross-over pragmatic clinical trial in four academic-affiliated clinics, we compared captured immunization opportunities during patient visits when the reminder was "on" versus "off" for the primary immunization series, school-age boosters, and adolescents. We also assessed coverage of CMC-specific immunizations. Up-to-date immunization was measured by end of quarter. Rates were compared using chi square tests.

Keywords
- clinical decision support
- graphical user interface
- immunization information system
- CMC-specific immunizations

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Results Overall, 15,343 unique patients were seen for 26,647 visits. The alert significantly impacted captured opportunities to complete the primary series in both well-child and acute care visits (57.6% on vs. 54.3% off, $p = 0.001$, and 15.3% on vs. 10.1% off, $p = 0.02$, respectively), among most age groups, and several immunization types. Captured opportunities for CMC-specific immunizations remained low regardless of alert status. The alert did not have an effect on up-to-date immunization overall (89.1 vs. 88.3%).

Conclusion CDS in this population improved captured immunization opportunities. Baseline high rates may have blunted an up-to-date population effect. Converting Centers for Disease Control and Prevention (CDC) rules to generate sufficiently sensitive and specific alerts for CMC-specific immunizations proved challenging, and the alert did not have an impact on CMC-specific immunizations, potentially highlighting need for more work in this area.

Background and Significance

Immunization is one of the most effective public health interventions to combat disease but coverage has consistently fallen short of national goals.[1] Children with chronic medical conditions (CMCs) often need specific additional immunizations or immunizations on a different schedule, though many fail to receive them.[2] It is important to identify children with immunization delay and provide catch-up immunizations at every opportunity.[3]

Immunization reminders for providers in the electronic health record (EHR) are a type of clinical decision support (CDS) that can reduce missed immunization opportunities.[4,5] One limitation of these reminders is that they generally rely only on data local to the EHR which can be incomplete due to record scatter and lead to inaccurate alerts.[6] Catch-up doses for children with delayed immunizations present an even greater challenge, as there are changes to both the dosage intervals and the number of immunizations needed.[7,8]

An immunization information system (IIS), or immunization registry, is a population-based system that collects immunization data primarily for children and adolescents from providers at the regional or state level.[9] In part, due to stage-3 meaningful use criteria set by the Centers for Medicare & Medicaid Services (CMS), many IIS now support bidirectional immunization exchange through which an EHR can retrieve additional immunizations from the IIS back into the local EHR,[10] allowing providers to receive more complete records of their patient's immunization records without having to log in to the IIS directly. Some also include forecasting in which the IIS gives recommendations for immunizations that are due; however, many do not include recommendations for CMC-related immunizations. Frontline care providers are most likely to benefit when accurate data and forecasting reminders from the IIS fit within their current EHR workflow.[8]

In this project, we sought to couple IIS bidirectional exchange of immunization information and forecasting tools with EHR patient-level medical history to deliver accurate, patient-specific EHR immunization reminders, including risk-based immunization recommendations for children with CMCs.

Objectives

Our objective was to assess the impact of EHR reminders using regional IIS CDS-provided rules on receipt of immunizations in a low-income, urban population for both routine immunizations and those recommended for patients with CMCs. We also developed CMC-related immunization recommendations in a local EHR.

Methods

Study Setting and Design

The trial was conducted in four community pediatric health clinics affiliated with the NewYork-Presbyterian Hospital (NYP) Ambulatory Care Network (ACN) and Columbia University Irving Medical Center who provide care to a primarily publicly insured and Latino population. The Vaccines for Children (VFC) Program provides the immunizations for free for nearly all patients at the study sites.

We conducted a randomized cluster–cross-over pragmatic clinical trial in the four sites from June 2017 to June 2018. Using the configuration tools in the EHR, each site had four phases each lasting 3 months, two for which the reminder was "on" and two for which it was "off," allowing each site to act as its own control while accounting for some seasonal variation (►Fig. 1). Study sites were academic-affiliated clinics with attendings, residents, academic pediatric fellows, and nurse practitioners as providers who received the alerts.

We designed an EHR-based immunization alert within the Allscripts Sunrise Clinical Manager (SCM) Ambulatory application. Upon note opening, the alert retrieved immunization information from EzVac, our hospital's immunization registry, which in turn synchronized data with New York City's IIS, the Citywide Immunization Registry (CIR) to provide real-time immunization recommendations for the patient a provider was seeing. The alert used an open-source rules-based engine provided by New York City's IIS through their

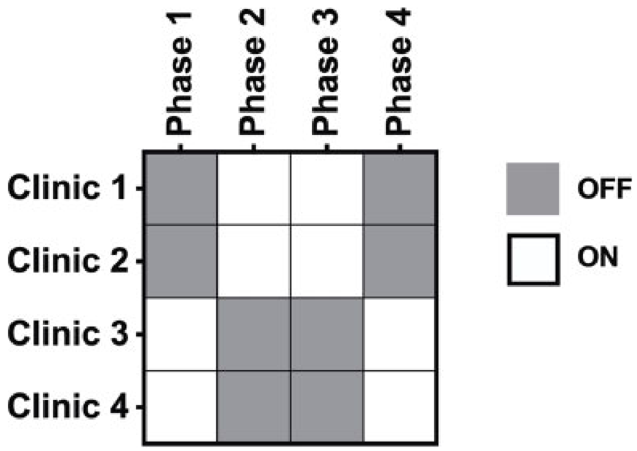

Fig. 1 Randomized cluster-crossover design in four academic-affiliated community health clinics from June 6, 2017 to June 5, 2018. Each phase represented a 3-month quarter.

vendor to power the CDS in the reminder for routine immunizations (►Supplementary Fig. 1, available in the online version).[11] Synchronizing with the city IIS allowed the reminder to act on the most up-to-date information available for individual patients.[12] Accuracy of the alert was verified extensively with test patients designed to test the various aspects of the alert and its logic, and a usability test was conducted with a small group of physicians prior to beginning the trial. This is in addition to the testing that was completed by the vendor to ensure that the rules used by the CIR are correct. The engine was kept up to date and was updated seven times during the study.

In addition, we programmed rules for the additional immunizations needed for children with CMCs. These CMCs were identified based on Advisory Committee on Immunization Practices (ACIP) recommendations and existing literature and matched with the International Classification of Diseases, 9th and 10th revisions (ICD-9 and ICD-10, respectively) codes. When the reminder launched, it additionally queried the patient problem list in the EHR and provided the additional immunization decision support for children with CMCs based on the ICD codes (Supplementary Material S1, available in the online version).

A user survey was distributed to attendings, residents, nurses, and nurse practitioners who used the alert during the study period. The Synchronized Immunization NotifiCations (SINC) survey was distributed via e-mail and completed in Qualtrics, an electronic survey platform (Supplementary Material S2, available in the online version).

Outcomes

For children ages 0 to 18 years who had visited during the study period, we electronically abstracted immunization information from the EHR, as well as information regarding their CMCs at the time of their visits.

Captured opportunities were defined as a medical visit in the study period during which a child/adolescent was eligible and received an immunization. For the captured opportunities analysis, patient ages were divided into: overall, 0 to 12 and 12 to 23 months and 2 to 3, 4 to 6, 7 to 10, 11 to 12, and 13 to 17 years. Immunizations due at time-of-visit varied based on patient age and up-to-date immunization status and included diphtheria, tetanus, acellular pertussis (DTaP), inactivated poliovirus (IPV), *Haemophilus influenzae* type b (Hib), hepatitis B (HepB), rotavirus (RV), measles, mumps, rubella (MMR), varicella (VAR), pneumococcal conjugate (PCV13), hepatitis A (Hep A), meningococcal (MenACWY), tetanus, diphtheria, acellular pertussis (Tdap), tetanus, diphtheria (Td), and the human papillomavirus (HPV) immunization.

We used the Centers for Disease Control and Prevention (CDC) recommended immunization schedule to determine captured opportunities. For ages up to 2 years, all children should receive the Healthcare Effectiveness Data and Information Set (HEDIS) Combo 3 series (4:3:1:3:3:1:4) as appropriate for their age which includes 4 DTaP, 3 IPV, 1 MMR, 3 Hib, 3 Hep B, 1 VAR, and 4 PCV doses. They should also have received $\geq$2 RV and 2 Hep A. By age 7 years, they should have received the DTaP, IPV, MMR, and VAR boosters. By age 13 years, all adolescents should receive the HEDIS Combo 2 (1:1:2) adolescent immunizations which include 1 Tdap, 1 MenACWY, and 2 HPV immunizations. They also should have received a MenACWY booster by age 17 years.

For children $\geq$2 years with eligible CMCs, who were due for additional immunizations, we analyzed any receipt of any dose of pneumococcal polysaccharide (PPSV23; one to two doses after 2 years of age, condition dependent) and receipt of any dose of MenACWY immunization (dosing age and condition dependent). For children requiring PPSV23, we also included receipt of PCV-13 after age 2 years, as captured opportunities in our analysis when needed prior to PPSV23 doses, and this was also recommended by our immunization alert.

Under-immunization was defined as the percent of children and adolescents who were overdue for at least one age-appropriate immunization as recommended by the CDC's ACIP, by the end of each 3-month study period for those patients seen during that period. Study ages included children of 7 to 12 and 19 to 48 months, 7 to 11, 13 to 16, and 17 to 18 years. These ages were chosen, as children receive certain immunizations before each of these age groups and would be considered overdue if they were still due for immunizations at these ages.

Statistical Analysis

Based on immunization and visit data, as well as previous studies, we expected there to be 12,380 unique children with visits in any given 6-month period, reflecting the combined "on" and "off" phases for each site. We expected when the reminder is "off" that at the end of any given visit, 85% of children would be fully immunized (this included those who at the beginning of the visit were not due for any immunization, as well as those who were due for an immunization and received it), and 15% would be not up-to-date. Based on this sample size and 80% power, we were powered to detect absolute unadjusted differences in the proportion of children who are not up-to-date on their immunizations (i.e., under-immunized) of 1.3%.

We compared captured opportunities and under-immunization when the reminder was "on" versus "off" for all children with visits during the study period. We also assessed coverage of CMC-specific immunizations including PPSV23 and MenACWY. The list of individual patients with an eligible CMC for which the alert fired for was reviewed by one of the pediatrician study investigators to ensure that the patient was actually due for that CMC-related immunization. Analyses were stratified by age and visit type (well child care vs. acute care visits). Immunization rates were compared using Chi-square tests.

Statistical analyses were performed in SAS v 9.4 (SAS Institute Inc., Cary, NC). This study was approved by the Columbia University Irving Medical Center Institutional Review Board with a waiver of consent.

Results

Overall, there were 15,348 unique patients seen over the study period including 26,647 visits. Half (49.5%) of the children were female, nearly all (97.4%) were publicly insured, and a little over half (52.7%) spoke Spanish (►Table 1).

Table 1 Demographic characteristics of the study population

Variable	Frequency ($n = 15,348$)	Percent
Gender		
Female	7,598	49.5
Male	7,750	50.5
Ethnicity		
Hispanic or Latino	4,306	28.0
Non-Hispanic or Latino	789	5.1
Other	10,253	66.8
Race		
White	1,591	10.4
Black	771	5.0
Asian	65	0.4
American Indian	4	0.0
Native Hawaiian/ Pacific Islander	90	0.6
Other	12,827	83.6
Insurance		
Commercial	543	3.5
Public	14,532	94.7
Uninsured	265	1.7
Other	8	0.1
Language		
English	6,300	41.1
Spanish	8,089	52.7
Other language	959	6.3

Captured Opportunities

During the study period, there were 10,802 visits in which a child was due for an immunization in 4:3:1:3:3:1:4 series. There was a small but significant difference in captured opportunities to complete the entire recommended series when the alert was "on" versus when it was "off" (54.0 vs. 50.3% $p = 0.0001$; difference 3.7%; 95% confidence interval [CI]: [1.8–5.6%]). There was a significant difference in both acute and well child visits (►Fig. 2), as well as across most of the age groups (►Fig. 3). The alert improved captured opportunities for patients seen by attending physicians for some age groups including patients under 12 months, patients of 12 to 24 months, and overall (data not shown).

There were 2,735 visits during the study period in which an adolescent was due for an immunization in the 1:1:2/3 series; however, there was no significant difference in captured opportunities when the alert was "on" versus "off" (52.9 vs. 49.7%, $p = 0.1$; difference = 3.2%; 95% CI: [0.6–6.9%]). There was also no difference when stratified by visit type well child care versus acute care visits (data not shown).

In addition, captured opportunities were stratified by immunization type. A few of the immunization types including Hep B, Hib, and Hep A were more likely to lead a significant increase in captured opportunity during the "on" periods for alert versus the "off" periods (►Fig. 4).

Underimmunization

There was no measurable difference in overall immunization up-to-date status in patients of study ages by the end of quarter when the alert was "on" versus "off" (89.1 vs. 88.3% $p = 0.16$; difference = 0.8%; 95% CI: [−0.3 to 1.8%]).

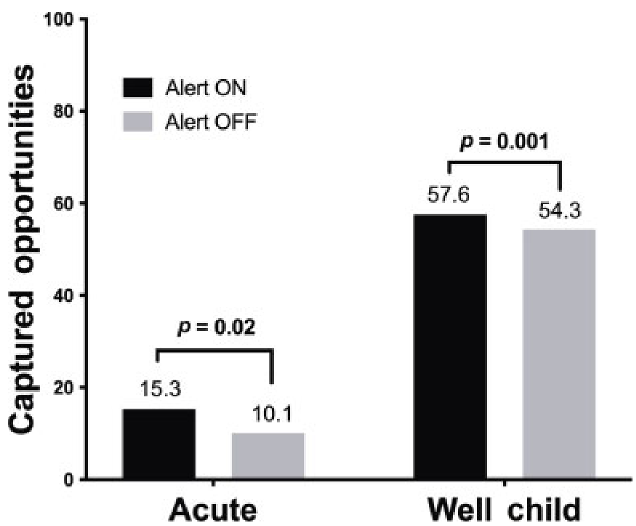

Fig. 2 Captured opportunities when the immunization alert was "On" versus "Off" for the primary immunization series (4:3:1:3:3:1:4) by visit type well child care versus acute care visits. Note: The series includes age-appropriate doses of diphtheria, tetanus, and acellular pertussis (DTaP), poliovirus (IPV), measles, mumps, and rubella (MMR), *Haemophilus influenzae* type b (Hib), hepatitis B (Hep B), varicella (VAR), and pneumococcal 13-valent conjugate (PCV13) immunizations.

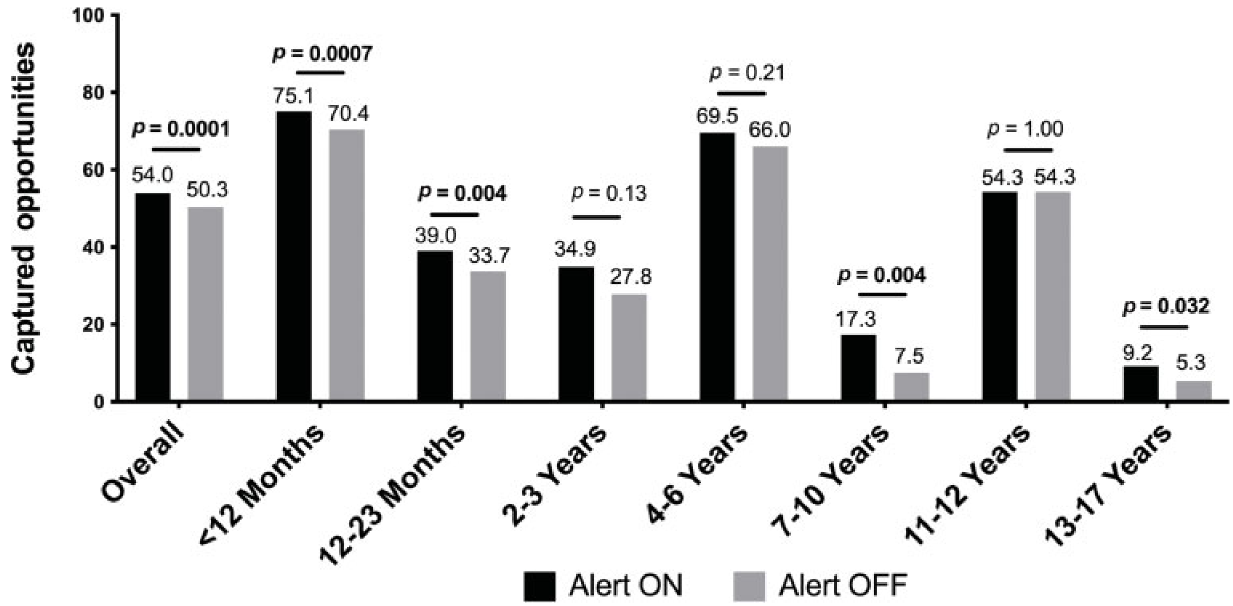

Fig. 3 Captured opportunities when the immunization alert was "On" versus "Off" for the primary immunization series (4:3:1:3:3:1:4) by age. Note: The series includes age-appropriate doses of diphtheria, tetanus, and acellular pertussis immunization (DTaP), poliovirus immunization (IPV), measles, mumps, and rubella immunization (MMR), *Haemophilus influenzae* type b immunization (Hib), hepatitis B immunization (Hep B), varicella immunization (VAR), and pneumococcal 13-valent conjugate immunization (PCV13).

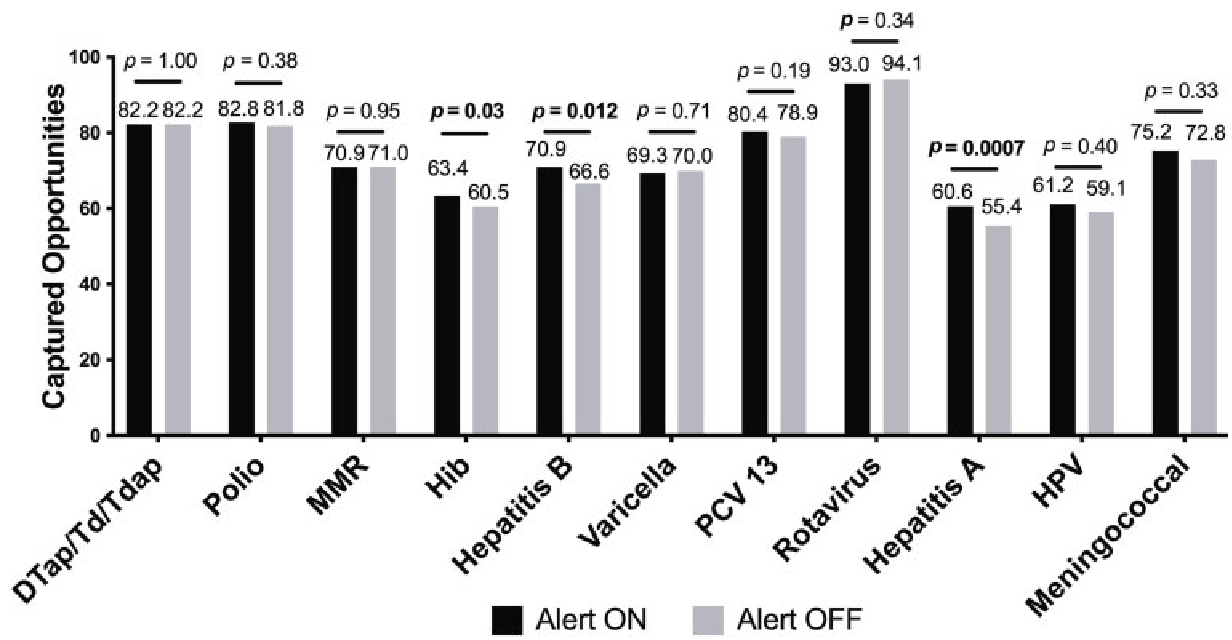

Fig. 4 Captured opportunities when immunization alert was "On" versus "Off" by immunization type. Note: Immunizations include age-appropriate doses of diphtheria, tetanus, and acellular pertussis immunization (DTaP), poliovirus immunization (IPV), measles, mumps, and rubella immunization (MMR), *Haemophilus influenzae* type b immunization (Hib), hepatitis B immunization (Hep B), varicella immunization (VAR), and pneumococcal 13-valent conjugate immunization (PCV13), tetanus, diphtheria, and acellular pertussis v immunization (Tdap), meningococcal serogroups A, C, W, Y immunization (MenACWY), and human papillomavirus immunization (HPV).

Immunizations for Children with Chronic Medical Conditions

Two percent of children seen during the study period were eligible for CMC-related pneumococcal immunization. Overall up-to-date status for PPSV23 remained low for the 299 children seen during the year with a qualifying condition, when the alert was "on" versus "off" (23.6% [$n = 35$] on vs. 24.5% [$n = 37$] off, $p = 0.9$; difference = 0.8%; 95% CI: [−10.5 to 8.8%]); captured opportunities were also low (9.7% [$n = 12$] on vs. 3.6% [$n = 4$] off, $p = 0.06$; difference = 6.1%; 95% CI: [−0.5 to 12.9%]). Less than 1% of children seen during the study period were eligible for CMC-related meningococcal immunization. Overall up-to-date status for the 35 children who had a qualifying condition for the MenACWY immunization and were seen during the study period was high both when the alert was "on" versus "off" (73.7% [$n = 14$] vs. 87.5% [$n = 14$], $p = 0.31$; difference $= -13.8\%$; 95% CI: [−38.0 to 13.8%]). Captured opportunities during the study period were low (9.1% [$n = 1$] "on" vs. 15.4% [$n = 2$] "off," $p = 0.64$; difference $= -6.3\%$; 95% CI: [−34.2 to 24.4%]). There was no significant difference in captured opportunities for patients with CMCs seen by attending physicians (data not shown).

User Survey

Overall, 63 providers and 14 nurses completed the user survey out of a total of 127 nurses, residents, nurse practitioners, and attendings (response rate 61%). Almost all respondents (95%) were at least somewhat satisfied with the immunization alert, and 96% found the alert at least somewhat helpful. However, 45% of respondents reported encountering at least one problem when using the immunization alert, primarily with the alert not working properly for some patients. Some respondents (21%) questioned the accuracy of the immunization reminder or stated that it displayed incorrect immunization history.

Discussion

The immunization alert which synced with the city immunization registry and gave real-time recommendations for immunizations due at visits, was associated with improved captured opportunities across all visit types, in many age groups, and for several immunizations. The success of the alert in improving captured opportunities is consistent with the body of literature supporting EHR reminders as a tool to improve immunization rates.[6,13–24] Interestingly, the impact on captured opportunities was seen not only in acute care visits where missed opportunities are expected, but it was also observed in well child checks where health care providers should have an increased attention toward immunizing. The alert may have increased the likelihood that there was catch-up of immunization doses, and this is supported by the specific captured opportunities for the Hep B, Hib, and Hep A immunizations which have more complex intervals and rules relating to catch-up vaccination.

Despite this, not all opportunities were captured. The rate of captured opportunities for when the alert was "on" was lower than expected, particularly during well child visits (57.6%) and overall for the primary 4:3:1:3:3:1:4 immunization series (54%). There are medical reasons the health care provider could have chosen not to immunize that day, such as the child having an acute illness or high fever.[25] A provider may also not have wanted to give more than a certain number of immunizations at a time, that is, only four immunizations at the 1-year visit, although the alert often displayed five to six immunizations due depending on if it was influenza season. The additional immunizations not given would appear as "missed opportunities" in our analysis even though providers were following the routine schedule. Other possible reasons for not immunizing could be logistical, such as the family not having time to wait to receive the immunization that day, or attitudinal, as parents who are vaccine hesitant may ask to delay or outright refuse immunizations.[26] Alternatively, the provider could have failed to recommend an immunization or provided a weak recommendation.[27,28] In addition, for patients who received immunizations outside of New York City, the alert would not include that information, so providers may not immunize until they have complete records for the patient to avoid over-immunizing. Technical and trust issues could have also affected the impact of the alert. In a survey of providers and nurses who used the alert, almost half (45%) of respondents reported at least one technical issue with the alert. Many of these issues were described as the alert not displaying properly especially for new patients. In the handful of "errors" reported to the research team, the alert was indeed correct and the patient was in need of immunization. Examples of the "errors" reported included interval issues with the Hep A immunization (<6 months in between doses), live attenuated immunizations (e.g., MMR and live attenuated influenza immunization) given too close to one another, among others. Some providers may have been hesitant to give immunizations long after the error in immunization administration was made to rectify these issues. When looking at captured opportunities for attending physicians only, the immunization alert was significant for patients overall and age 2 years and under only but not for other ages as it was for other providers. The difference could be from attending physicians not referring to the alert or not believing it was correct. Other studies have shown increased use of CDS alerts over time, and a longer study period might have improved provider trust in the alert.[29]

In contrast, there was no statistical difference seen when looking at overall up-to-date immunization status for the recommended series across the population. Overall, immunization coverage rates were high across all sites which blunted the potential of the alert benefit. Although the immunization alert may have been useful to individual providers treating individual patients, little impact was shown at a population level in a setting with high baseline immunization rates. In addition, the 1-year study period may have been too short to see an improvement in overall immunization rates. When analyzing an up-to-date status for immunization series, we looked at study ages at which time children would be overdue for immunizations if they had not yet received them. For the adolescent series, this would be at ages 13 to 15 years, so the overall up-to-date status wouldn't capture patients, for example, who received immunizations at 11 or 12 years of age but did not turn 13 years during the study period.

The limitations above could have also played a role in the lack of alert's effect for children with CMCs requiring specific immunizations, but there are also other likely causes for this finding. During visits with children with CMCs, the alert would highlight when a patient could possibly require a condition-specific immunization. The alert directed the provider to the patient's "problem list" and a link to the CDC's overall medical condition-specific recommendations instead of directly identifying the triggering condition or spelling out the CDC CMC guidance. More specific guidance in the alert paired with an order for the specified immunization might have made the alert more effective. Other investigators have, for example, reported the need for more specific alerts specifying whether the PCV13 versus PPSV23 immunization is due to improve the chances that providers would act on CDS for children with kidney transplants.[30] Others have also developed immunization alerts for a specific medical condition[31] or to recommend the influenza immunization for children with CMCs[32]; however, we are not aware of investigators who have developed an alert that encompasses multiple CMC-related immunizations and numerous CMCs.

It also proved to be a complicated task to convert the CDC immunization guideline text into disease-specific ICD-9 and -10 codes. Because coding in the problem list varied substantially, even for the same condition, we had to determine how liberal we would be in identifying codes that could possibly indicate a condition. We opted to increase the sensitivity of the alert by including parent codes that could be used to code for a qualifying condition for which the immunization would be needed, but which could unfortunately also code for a condition for which the immunization may not be needed. We educated providers on these features, as well as noting in the alert that the end user should check the conditions, to confirm whether or not the immunization was needed. The need to confirm may have acted as a barrier. In addition, provider alert fatigue could have been introduced if the alert triggered for patients who were not actually due for the immunization. This could also have enhanced provider distrust. It is possible that with an EHR system where billing is structured and conditions are more likely to be coded the same way and with more specificity, an alert could rely on more specific ICD codes in turn allowing for much more alert specificity. This would need to be balanced with sensitivity.

Another possible explanation for low rates of CMC-related immunizations could be provider judgement. Some providers may not be familiar with the need for additional immunizations for children with CMCs. We expected this to be true for many resident physicians who are still learning the immunization schedule. However, when we analyzed captured opportunities and overall up-to-date status by end of quarter for patients seen by attending physicians who required CMC-related immunizations, we also saw no statistically significant improvement with the alert. Some CMCs leave little room for ambivalence about opting for CMC-related immunization such as children with sickle cell disease who have functional asplenia and are at high risk of infection from *Streptococcus pneumoniae* and *Neisseria meningitis*.[33] In our analysis, all but one patient who qualified for MenACWY had a form of sickle cell anemia which likely made it easier for providers to recognize that the patient was clearly due for the immunization as evidenced by higher baseline MenACWY immunization rates. However, for other conditions, it may be less clear to a provider that an immunization is needed since the CDC categories can be broad (e.g., liver disease). In other cases, the patient may be doing clinically well or have mild disease, and a provider may believe that the CMC-related immunization is not necessary. A pediatrician on the research team reviewed each patient's CMC diagnoses and removed patients with conditions that were deemed ineligible for MenACWY or PPVS23 immunizations prior to data analysis; therefore, the analyses were limited to those who really were in need of immunization. However, we used a more conservative approach including patients with all indications including mild disease in the denominator for CMC-related immunizations which may be contributory to low immunization rates overall. More specific ACIP guidelines for CMC-related immunizations could include immunization-related guidance specific to the severity of the disease in addition to more clearly delineating which conditions should be included, thus ensuring that all children with CMCs who need CMC-specific immunizations receive them.

A fair amount of work is needed to keep rules up-to-date highlighting the potential for open-source centralized rule-based engine such as these; if EHR vendors used such engines, they could reduce redundancies and more easily ensure they are always using the most up-to-date rules.[8] It would be important that systems are in place to ensure updates are not missed. Such rule-based engines are helpful for routine immunizations but may be more limited for immunizations needed for high-risk conditions. While the engine used in this study highlighted when immunizations may be needed for high-risk conditions, it did not have a list of ICD-9 or -10 codes that would constitute conditions that could necessitate that immunization. Having this in the future would potentially be useful, so that individual sites are not trying to create a list of codes themselves. However, the caveats of the sensitivity and specificity balance as discussed above would need to be addressed.

Limitations

There were several limitations to this study. Our population had baseline high immunization rates which created a ceiling effect with little room for improvement with the intervention. Few patients required CMC-related immunizations; therefore, power in the analysis of CMC-related immunizations was low. In addition, for CMCs, the rules engine did not have a list of ICD-9 or -10 codes that would constitute conditions that could necessitate that immunization. Therefore, lists of relevant medical conditions were generated manually but may have included some conditions in grouped ICD-9 or -10 codes that did not necessitate CMC-specific immunizations. Sites may also have had differing immunization practices; however, the design of our study was a cluster cross-over trial which compared sites that had the alert with those that did not which should account for these differences. Finally, this study also took place in a single medical system, findings may not be generalizable to other settings.

Conclusion

Ultimately, it was possible to build an immunization alert in an EHR that used a centralized immunization rules engine, as well as synchronized data, with the local IIS. Immunization

CDS in this population did improve captured opportunities for immunization providing individual children with their needed immunizations. While we did not see a population-level effect due to high baseline immunization rates, such an alert may be helpful across a population at sites that are not routinely checking for needed immunizations at all visits. The alert did not have an impact on condition-specific immunizations for children with CMCs. More precise coding may be needed to be able to launch sensitive and specific alerts that are more actionable for the end users, as well as more clarity and specificity in the rules themselves.

Clinical Relevance Statement

This manuscript reaffirms current literature which demonstrates that clinical decision support (CDS) immunization reminders embedded in the electronic health record (EHR) improve immunization uptake for several immunizations and visit types. We developed an alert that encompasses multiple chronic medical condition (CMC)-related immunizations and numerous CMCs which is not previously reported in the literature. Use and trust in the reminders are important to their effectiveness. This paper further explores the need for more specific and sensitive reminders for immunizations based on patient medical conditions, as there was no statistically significant improvement in immunizations needed for patients with CMCs and suggests that more research should be done to better improve CDS systems for patients with CMCs.

Multiple Choice Questions

1. What is/are the benefit(s) of having electronic health records (EHR) synchronize with immunization information systems (IIS)?
   a. To improve captured opportunities for immunization
   b. To satisfy HIPAA requirements
   c. To comply with meaningful use requirements
   d. Choices A and C

   Correct Answer: The correct answer is option d. Stage-3 meaningful use criteria set by the Centers for Medicare & Medicaid Services (CMS), require many EHR to participate in bidirectional immunization information exchange. This allows local EHR to display immunizations from the IIS allowing providers to receive more complete records of their patient's immunization records without having to log in to the IIS directly. Synchronizing with IIS helps prevent over-immunization by displaying immunizations which may have been administered at different locations in the EHR and providing a more complete record.

2. Which of the following immunizations is given in an additional to the primary immunization series for children with certain chronic medical conditions such as heart disease or diabetes?
   a. *Haemophilus influenzae* type b (Hib) immunization
   b. Pneumococcal polysaccharide (PPSV23) immunization
   c. Diphtheria, tetanus, acellular pertussis (DTaP) immunization
   d. Pneumococcal conjugate (PCV13) immunization

   Correct Answer: The correct answer is option b. The pneumococcal polysaccharide immunization (PPSV23) is recommended for children ages 2 to 5 years with several chronic medical conditions including chronic heart disease; chronic lung disease; diabetes mellitus; cerebrospinal fluid leak; cochlear implants; sickle cell disease and other hemoglobinopathies; anatomic or functional asplenia; congenital or acquired immunodeficiency; HIV infection; chronic renal failure; nephrotic syndrome; malignant neoplasms, leukemias, lymphomas, Hodgkin's disease, and other diseases associated with treatment with immunosuppressive drugs or radiation therapy; solid organ transplantation; multiple myeloma: chronic liver disease, and alcoholism. This PPSV23 immunization is recommended in addition to the PCV13 series and should be given after the completion of the PCV13 series when possible.

Note

This study is registered with ClinicalTrials.gov, identifier: NCT02710318—Synchronized Immunization NotifiCations (SINC).

Protection of Human and Animal Subjects

The study was performed in compliance with the World Medical Association Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects and was reviewed and approved by the Columbia University Irving Medical Center Institutional Review Board.

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Conflict of Interest

A.M.H. received support from the Pfizer Medical Education Group for an unrelated investigator-initiated study; M.S.S. was a coinvestigator but received no financial support. Other authors have no conflicts of interest to disclose.

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