Title of Project: Improving Influenza Vaccine Uptake in Acute Care Settings

Principal Investigator and Team Members:

PI: Evan Orenstein, MD
Co-I: Swaminathan Kandaswamy, PhD

Organization

Emory University

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Federal Project Officer

Lingrui Liu (lingrui.liu@ahrq.hhs.gov)

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Structured Abstract

Purpose: Pediatric influenza vaccination rates remain sub-optimal. Hospitalized children are at especially high risk from influenza-related morbidity. We aimed to (1) develop a suite of clinical decision support (CDS) strategies to improve inpatient influenza vaccination rates in children and (2) determine their implementation effectiveness over time.

Scope: This study was performed at a single pediatric health system in the Southeastern United States with 3 freestanding children's hospitals. Interventions were implemented using a sequential crossover design from control to intervention.

Methods: We developed 3 CDS tools: (1) prechecked influenza vaccine order groups dynamically added to admission order sets (implemented 2019-2020 season), (2) non-interruptive vaccine status notifications (implemented 2020-2021 season), and (3) a conditional discharge alert to nudge nurses to administer influenza vaccine prior to discharge (implemented 2020-2021 season). We evaluated their influence on influenza vaccine administration rates from 9/1/2018 through 5/1/2022 using mixed effects logistic regression adjusting for influenza season and demographic factors.

Results: There were 46,706 eligible hospitalizations across the four influenza seasons. In multivariable analysis, all three CDS interventions significantly improved influenza vaccine rates (influenza vaccine order group: aOR 2.27, 95% CI, 2.13-2.41; conditional discharge alert: aOR 1.83, 95% CI, 1.57-2.12; vaccine status notifications: aOR 1.19, 95% CI, 1.03-1.36). Vaccination was highest in the 2019-2020 influenza season with failing rates in the subsequent years (2021-2022 season: aOR, 0.34, 95% CI, 0.29-0.41). While CDS improved influenza vaccination rates in hospitalized children, decreased rates over time may indicate waning CDS effectiveness or external factors such as increased vaccine hesitancy and provider challenges over the same time period.

Purpose (Objectives of Study)

Our long term objective was to identify clinical decision support (CDS) strategies that improve uptake of recommended health maintenance interventions in acute care settings. The goal of this proposal was to develop a CDS process that improves influenza vaccine uptake among eligible hospitalized patients in our health system.

Aim 1: Design CDS to promote influenza vaccine uptake in pediatric acute care settings with a user-centered design (UCD) approach.

Aim 2: Evaluate implementation effectiveness using the RE-AIM framework.[1]

- Reach: proportion of patients for whom the CDS intervention fired with an influenza vaccine order.
- Efficacy: proportion of eligible patients to whom influenza vaccine is administered prior to discharge
- Adoption: (1) proportion of unit operational leaders willing to incorporate the CDS in their care area and (2) proportion in each unit of ordering clinicians who ordered vaccine and nurses who administered it.
- Implementation: (1) observed fidelity of ordering clinicians and nurses to intervention procedures and (2) estimated cost of developing and disseminating the intervention in the 2020-2021 influenza season
- Maintenance: (1) efficacy in the 2021-2022 influenza season, (2) estimated cost for sustaining the intervention, and (3) presence of organizational policies for influenza vaccine in acute care settings.

Scope

Background

Influenza vaccination prevents millions of illnesses, medical visits, and thousands of hospitalizations, and deaths due to influenza viruses.[2,3] Despite these benefits, the percentage of children in the United States receiving ≥1 dose of influenza vaccine during the 2020–21 season was only 58.6%.[4] Hospitalized children often have chronic conditions and are at higher risk of influenza related morbidity and mortality.[5] In addition, children from communities with low household income are more likely to be hospitalized, less likely to have medical homes[6] and therefore often have fewer opportunities for immunization.[7,8] Yet, influenza vaccination rates in hospitalized children are lower than the national average in the US.[9,10] Many hospitalized children have had at least one missed opportunity for vaccination, highlighting the potential for improving vaccination during hospitalization.[10] The Centers for Disease Control and Prevention Advisory Committee on Immunization Practices recommends vaccination of eligible children

during every healthcare encounter.[11] However, influenza vaccination is often not considered a high priority during acute care visits.[12] Major reasons for missed opportunities include lack of knowledge about immunization status and inappropriate understanding of contradictions.[13] Missed opportunities for influenza vaccination among children are often repeated from one influenza season to the next[14] and the importance of identifying strategies to identify and vaccinate vulnerable children has increased in the setting of the COVID-19 pandemic.[15]

Multiple studies have reported efforts to improve vaccination in hospitalized children.[16] Examples include: (1) an automated nurse-facing electronic screening tools to determine eligibility for influenza vaccine that facilitated vaccine ordering without requiring involvement of a provider,[17] (2) a combination of family education, staff education on screening of patients, vaccine ordering, and documentation of refusals/contraindications as well as vaccine order built into admission order sets,[18] (3) a manually generated weekly email reminder to clinical teams,[19] (4) a bundled intervention including education modules, huddles and reminders for nurses, financial incentives for residents, and an automatically generated list of eligible patients in the electronic health record (EHR),[20] and (5) another bundle including provider and family education, hospital-wide vaccination tracking tool, and an institutional, nurse-driven vaccine protocol.[9] However, most of these interventions required ongoing maintenance, and the association of each intervention bundle element with the outcome was unclear.

Birmingham et.al. identified key characteristics providers desired in an alert for improving influenza vaccination including (1) reminding providers early in the visit, (2) accurately determining patients' immunization status, (3) enabling easy vaccine ordering, and (4) generating appropriate documentation in the EHR.[21] We hypothesized that user-centered design[22,23] of CDS mindful of these desires and CDS implementation recommendations[24] would significantly improve influenza vaccine uptake in acute care settings.

Setting

Children's Healthcare of Atlanta is a large pediatric health system in the Southeastern US with 3 freestanding hospitals including one academic tertiary care center (hospital A), one community tertiary care center (hospital B), and one academic secondary care center (hospital C). Influenza vaccines were available at all 3 sites generally from September through April of each year. At the beginning of influenza season each year, a special grand rounds was devoted to reviewing influenza burden, new guidelines, and promoting the influenza vaccine.

Context and Baseline Prevalence of Influenza Vaccination

This study was begun with interventions in the 2019-2020 influenza season. Prior to the study, a noninterruptive alert in the discharge navigator appeared for hospitalized patients aged 6 months or older with no record of influenza vaccine in the local database or state immunization registry for the current influenza season. During the baseline period (September 1, 2018, to May 1, 2019), this alert was ignored 94% of the time that it appeared (23,632 of 25,276), with an influenza vaccine order placed only 2% of the time (409 of 25,276). Of the 1609 influenza vaccine orders placed in the baseline period, 409 (25%) were placed through this noninterruptive alert, with the rest placed as ad hoc orders. Of 6,743 eligible hospitalizations in the baseline period, 912 (14%) had an influenza vaccine administered prior to discharge.

Based on this framework, we implemented clinical decision support (CDS) during the 2019-2020 influenza season including an opt-out immunization questionnaire in the nurse triage section and pre-checked influenza vaccination orders integrated into admission order sets for eligible patients based on immunization records from state registry.[25] These interventions improved vaccination rates from 14% to 31% in the intervention group. We subsequently identified lack of a conversation between clinicians and patients as well as lack of clinician awareness of patients' vaccine eligibility as opportunities for further improvement.[26] We incorporated these findings into a series of interventions to improve influenza vaccination.

CDS embedded in the EHR can deliver patient-specific recommendations to encourage evidence-based practices. However, the impact of CDS on care process and patient outcomes has not been consistent.[27–29] It is critical to associate the impact of CDS with outcomes and understand individual components of interventions to enable adoption of specific strategies. In this study, we aimed to understand the impact of multiple CDS strategies on influenza vaccination rates and the maintenance of their effects over time.

Methods

Study Design

This study was conducted as a quality improvement (QI) initiative. To further elucidate the specific impact of individual interventions, each intervention was implemented with a sequential crossover design, where the intervention would be implemented in one setting while data were captured across multiple settings, and the intervention if effective in the first setting compared to controls would be propagated to other settings.

Data Sources/Collection

We queried the EHR to capture eligible patient encounters, vaccine orders and administrations, and data on patient demographics and complex chronic conditions. We defined eligible hospitalizations as encounters with (1) patient aged 6 months or older, (2) no influenza vaccine in our local EHR system or the state immunization registry for the current influenza season prior to the admission datetime, (3) no history of anaphylaxis to any influenza vaccine in the local EHR system.

We classified each eligible hospitalization as part of influenza vaccine order group intervention if at least 1 order was placed using an order set that included the influenza vaccine order group , although this order did not have to be for influenza vaccine itself, but served as a marker that the default influenza vaccine order was seen by a provider in the encounter of interest. We identified the vaccine status banners/patient list column intervention group based on the campus and service the patient was admitted to being consistent with where the intervention

had been implemented. Finally, all encounters in which the conditional discharge alert fired were included in the conditional discharge alert intervention group. We had 8 combinations of intervention groups with the three intervention (Such as encounters that had only the influenza vaccine order group intervention of the three interventions, encounters that had the order group and the conditional discharge alert but no vaccine status banner/patient list column, etc.).

We assessed patient demographics including age, gender, race, ethnicity, and insurance to look for disparities in vaccine administrations. The demographics data are based on what was documented in the EHR and are generally based on patient and family self-report from a set of discrete choices captured during the registration process. To account for patient acuity, we assessed the number of pediatric complex chronic conditions determined from active diagnoses in the problem list within in the EHR at the time of discharge.[30,31]

Interventions

2019-2020 influenza season

We performed a user and task analysis through informal interviews of key stakeholders in the influenza vaccination process, including general medical ward nurses, pediatric residents, pediatric hospital medicine attending physicians, and pharmacists, to identify barriers to vaccine administration and inform a suite of EHR interventions addressing those barriers Patients and families were not interviewed in the development of this intervention.

Nursing Admission Questionnaire Adjustments

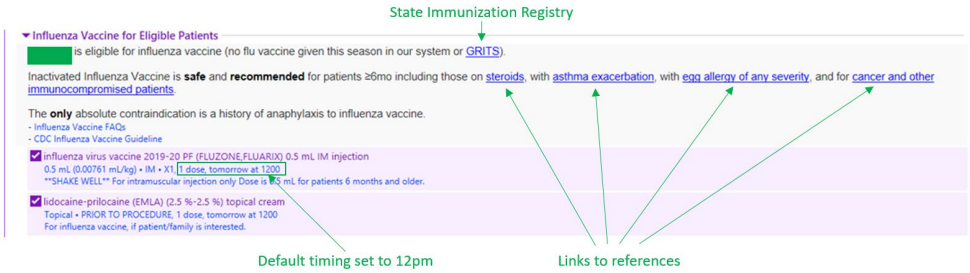
As part of the admission process, nursing staff members ask a series of questions of all parents. In the immunization section of the nursing administration questionnaire, we added questions with scripting designed to present the influenza vaccine using a presumptive communication strategy.

Influenza Vaccine Order Group

We developed an order group (Figure 1) including a default-checked influenza vaccine order automatically timed for 12 PM the day after admission, just-in-time education regarding influenza

vaccine appropriateness for specific populations (e.g., patients receiving corticosteroids, patients with asthma exacerbations, patients with egg allergy, patients with cancer, and other immunocompromised patients), as well as links to the state immunization registry, Centers for Disease Control and Prevention guidance, and supporting literature The order group would dynamically appear if the patient met the following criteria: (1) aged 6 months or older, (2) no influenza vaccine in our local EHR system or the state immunization registry for the current influenza season, (3) no history of anaphylaxis to any influenza vaccine in the local EHR system, and (4) no documentation by nursing staff indicating that the patient has already received influenza vaccine, has had an anaphylactic reaction, or parental refusal (see the Nursing Admission Questionnaire Adjustments subsection). If the nursing admission questionnaire was not filled out when the clinician accessed the orders and all other eligibility criteria were met, then the default-checked influenza vaccine order would show up in the admission order set. The clinician could manually unselect the influenza vaccine order from the order group if they chose. The order group was added sequentially to specific admission order sets as described in the Study of the Interventions subsection. The order group did not appear for patients 8 years of age or younger who had received 1 dose of influenza vaccine in the current season but had not received the influenza vaccine in any prior season and therefore should receive a second dose at least 4 weeks after the first dose.

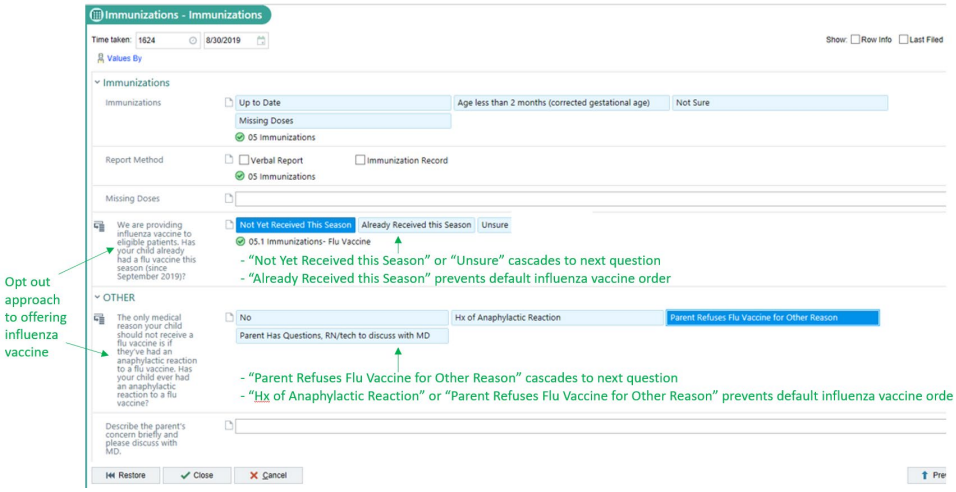
Figure 1: Dynamic Order Group Recommending Influenza Vaccine



Nursing Admission Questionnaire Adjustments: As part of the admission process, nursing staff ask a series of questions of all parents. In the immunization section of the Nursing

Administration Questionnaire, we added questions with scripting designed to present the influenza vaccine using a presumptive communication strategy (Figure 2).

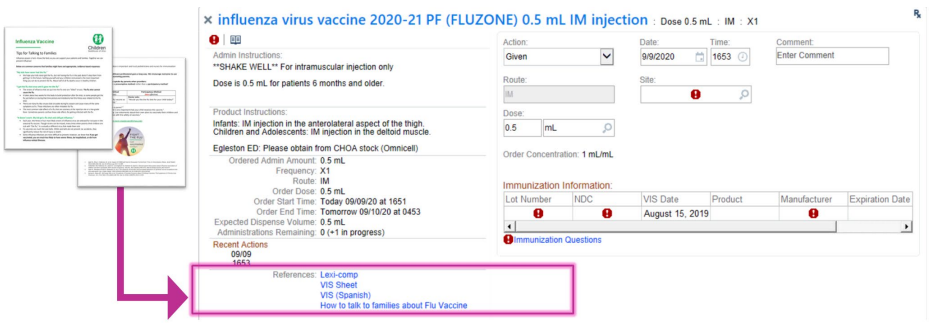
Figure 2: Nurse Influenza Vaccine Screening with Presumptive Strategy



Communication Tip Sheet

Our influenza vaccine working group, including infectious diseases specialists, worked with our marketing and parent and family advocacy groups to develop a tip sheet (Figure 3) focused on (1) the benefits associated with a presumptive method for introducing vaccines; (2) responses to common issues raised by families, such as "my kids have never had the flu," "I got the flu shot once and it gave me the flu," or "[the influenza vaccine] doesn't work"; and (3) vaccine facts, such as adverse effects and time to protection. We included a link to this tip sheet in the influenza vaccine order, which also appeared in the medication administration activity for nursing staff, but it was not immediately available in the nursing admission questionnaire.

Figure 3: Communication Tip Sheet from Medication Administration Record



A description of all 3 interventions was provided at educational sessions for nurses and residents and at an EHR physician oversight committee meeting prior to implementation. It was reviewed again with clinical department leaders prior to each stepwise implementation.

Analysis of Ongoing Barriers

After the 2019-2020 influenza season, we noted a substantial improvement in vaccination rates (see Results below) with overall vaccination rates improving from 14% at baseline to 31% in the intervention group. However, we noted remaining gaps, particularly between the frequency of influenza vaccine *orders* (77% of eligible hospitalizations in the original intervention group) and *administrations* (31% of eligible hospitalizations in the original intervention group).

We conducted a triangulation study including a retrospective analysis of nurse cancellation of influenza vaccine orders and interviews with front-line clinicians involved in the vaccine ordering and administration process. Based on these findings, we developed additional interventions in the 2020-2021 influenza season. No further interventions were added in the 2021-2022 influenza season.

2020-2021 influenza season

Vaccine Status Banner and Patient List Column:

In our analysis of ongoing gaps after the 2019-2020 season, we identified lack of conversations between provider teams and families as a barrier to vaccination.[26] To help clinicians follow up on influenza vaccine orders that had not yet been administered, we therefore built a non-interruptive banner that would appear on summary screens for nurses and physicians in the inpatient setting indicating their influenza vaccination status. (Figure 4). The banner had 3 status messages (1) patient is eligible for influenza vaccine and does not have an order, (2) patient has an active influenza vaccine order, but no influenza vaccine has been administered, or (3) influenza vaccine administered in this encounter. The same logic was used to create a patient list column indicating similar vaccine statuses for patients. (Figure 5). This column was automatically added to certain

shared patient list templates used by some pediatric residents and hospital medicine attendings at hospital A and was also available for providers to add to their individual patient lists. The banner and patient list column were implemented at Hospital A on 9/10/2020 and at Hospital B on 11/5/2020.

Figure 4: Banner Inside Patient Chart Indicating Influenza Vaccine Status

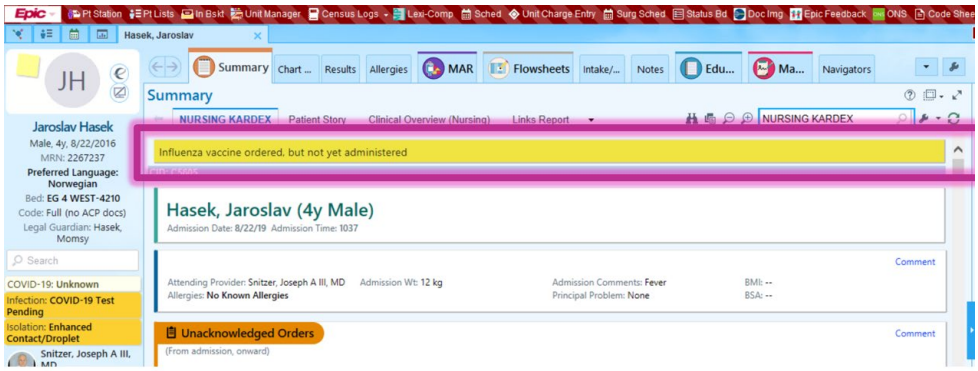
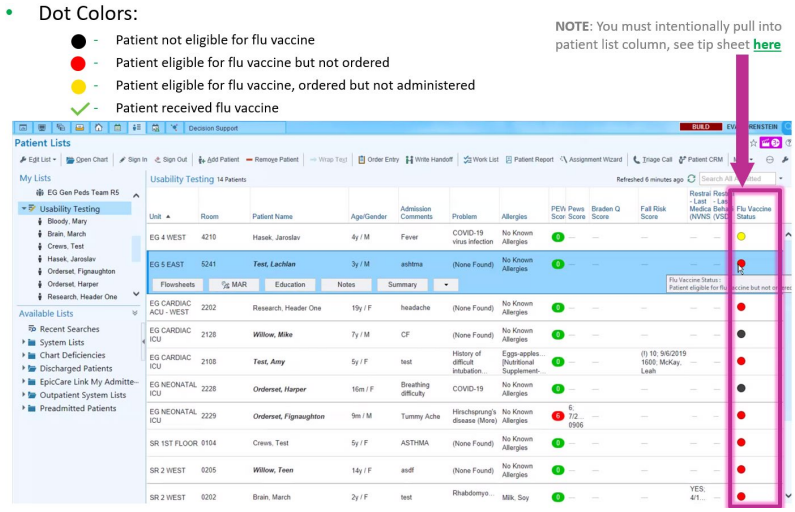


Figure 5: Patient List Column Indication Influenza Vaccine Status

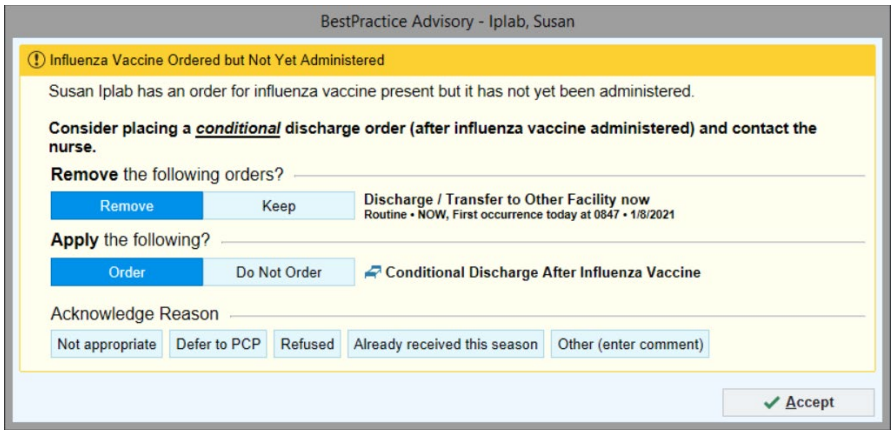


Conditional Discharge Alert:

We developed an alert (Figure 6) when the provider entered the discharge patient order if the patient had an active order for influenza vaccination but no administrations during the hospitalization. This alert would allow providers with one click to (1) add a comment on the discharge order to nurses asking them to conditionally discharge patient only after administering influenza vaccine and (2) change the discharge order frequency from “once” (i.e. discharge the

patient immediately) to “conditional” (i.e. discharge the patient once the conditions in the comments are met). The conditional discharge alert was implemented at Hospital A within the General Pediatric Service on 12/2/2020, and within the general pediatric service at Hospital B on 1/20/2021. This was expanded to all services at both hospitals on 9/8/2021.

Figure 6: Clinical Decision Support Recommending Conditional Discharge Order



Measures

Our primary outcome measure was the proportion of eligible hospitalizations with at least 1 dose of influenza vaccine administered prior to discharge. Our process measure was the proportion of eligible hospitalizations in which an influenza vaccine order was placed prior to discharge.

Limitations

This study has several limitations. First, it was performed at a single pediatric health system using one EHR vendor, Epic Systems©. Thus, findings may not be generalizable to other settings that differ based on organizational structure, pre-existing decision support and workflow patterns, technical infrastructure, and the culture of the catchment population especially with respect to vaccine attitudes. In addition, this study included hospitalizations before and during the COVID-19 pandemic. There were substantial swings in staffing, patient load, influenza burden and seasonality, and cultural attitudes toward vaccination during this period. While we were not able to account for all of these changes, our implementation approach using sequential crossover designs does provide greater confidence in the effectiveness of CDS interventions

relative to their absence given that both intervention and control settings were likely exposed to similar secular trends. Finally, a large proportion of patients were not vaccinated in the intervention groups, leaving substantial room for improvement.

Results

Principal Findings

Overall, we found that CDS significantly improved vaccination rates among hospitalized children and was acceptable and adopted across multiple care settings with substantial reach. Some of the non-interruptive interventions aimed at increasing the frequency of clinician-family conversations about vaccines did not have high implementation fidelity, often because the intervention was not perceived in the first place.

However, we also noted that while hospitalizations in which CDS appeared/was implemented consistently had higher influenza vaccination rates than those in which it did not, the overall impact of the influenza season had a similarly large or potentially even larger effect on vaccination rates. Specifically, the 2021-2022 season had an independent effect of reducing the odds of influenza vaccination by 66% (95% CI: 59% - 71%; see Outcomes below). This difference may be due to maintenance failures of our intervention in the absence of ongoing QI resources. However, it may also reflect a growing environment of vaccine hesitancy brought on by the COVID-19 pandemic and more prominent voices encouraging these perspectives. In particular, the persistently higher odds of vaccination with the intervention groups while the overall vaccination rate continued to fall increase the chances that the CDS remains effective over time but that external factors have reduced vaccination rates in nearly all settings.

Outcomes

From 9/2018 through 5/2022 (across four unique influenza seasons), there were 46,706 eligible hospitalizations in the four influenza seasons. The mean (SD) age was 8.46 (6.05) years, patients were mostly Black (21,702; 46.5%) or White (21,601; 46.2%), predominantly non-

Hispanic (39,851; 85.3%) and most (28,903; 61.9%) had public insurance. Compared to the no-intervention group, hospitalizations in the intervention group were more likely to include children with age group 13-17 years, Female sex, Black race, and higher number of complex chronic conditions, and lower likelihood of self-pay, though the magnitude of these differences was not large (Table 1).

The influenza vaccine administration rate was highest in the 2019-2020 influenza season at the start of the CDS interventions. (Figure 7). Over the years the total number of vaccine administrations dropped with the recent 2021-2022 season having only an 11 % (1,858/16,849) vaccination rate across all groups compared to a peak of 24.7% (2,684/10,880) in the 2019-2020 season.

In univariate analysis (Table 2), influenza vaccine administration was associated with the influenza vaccine order group intervention as well as the vaccine status banner and patient list column intervention. Vaccine administration was lower on univariate analysis for hospitalizations with the conditional discharge alert intervention and in patients with White race, non-Hispanic ethnicity, private insurance, and patients discharged on the weekend. Administration rates were higher in crude analysis for patients aged 2-4 years, patients with public insurance, Black and Asian patients, at Hospital C, and those who were discharged during day shift.

In multivariable analysis (Table 2), all 3 interventions were associated with higher odds of influenza vaccine administration, with the influenza vaccine order group increasing the odds by 2.27 (95% CI, 2.13-2.41), the conditional discharge alert increasing the odds by a factor of 1.83 (95% CI, 1.57-2.12), and the vaccine status banner and patient list column slightly improving the odds of vaccination (adjusted OR, 1.19 95% CI, 1.03-1.36). The influenza season was also strongly associated with the odds of vaccine administration, with 2021-2022 having 66% lower odds compared to the 2018-2019 season (adjusted OR, 0.34, 95% CI, 0.29-0.41). The week of the influenza season was also significantly associated with vaccine administration, with each

additional week into the season associated with a 5.2% reduction in the odds of receiving the influenza vaccine (adjusted OR, 0.94; 95% CI, 0.94-0.95). Adolescents were less likely to receive the influenza vaccine, with 13- to 17-year-old adolescents having 9% lower odds compared with 6- to 23-month-old children (adjusted OR, 0.91; 95% CI, 0.84-0.98). Asian and Black children were more likely to get the influenza vaccine with a 1.24 (95% CI, 1.08 - 1.41) and 1.11 (95% CI, 1.06 - 1.17) times higher odds compared to children of other races. Children discharged during the day shift were more likely to get the influenza vaccine with a 1.27 (95% CI, 1.15 - 1.41) times higher odds compared to children discharged during night shift. Children admitted over the weekend had slightly higher odds of vaccination, while those discharged over the weekend had slightly lower odds. No other demographic characteristics, including sex, race/ethnicity, insurance, or complex chronic

Table 1: Comparison of demographics and vaccination rates between intervention and control groups

Characteristic	No Intervention N (%)	At least 1 Intervention N (%)	*P*
Age			
Mean (SD), years	8.1(6)	8.7(6.1)	<0.01
6-23Months	3826 (21.9)	5229(17.9)	<0.01
2-4Years	3386 (19.3)	5788(19.8)	
5-12Years	5458 (31.2)	8998(30.8)	
13-17Years	4059 (23.2)	7642(26.2)	
18+Years	775 (4.4)	1545(5.3)	
Gender			
Female	8222 (47)	14111(48.3)	<0.1
Male	9282(53)	15091(51.7)	
Race			
White	8187(46.8)	13414(45.9)	0.08
Black	7986(45.6)	13716(47)	<0.01
Asian	545(3.1)	930(3.2)	0.69
Other	93(0.5)	175(0.6)	0.38
Unknown	1429(8.2)	1992(6.8)	<0.01
Ethnicity			
Hispanic or Latino	2555(14.6)	4172(14.3)	0.36
Not Hispanic or Latino	14890(85.1)	24961(85.5)	0.23
Unknown	59(0.3)	69(0.2)	0.05
Insurance			
Public	10759(61.5)	18144(62.1)	0.15
Private	6102(34.9)	10307(35.3)	0.34
Self-Pay	643(3.7)	751(2.6)	<0.01
Complex Chronic Condition			
Mean (SD)	0.4(1.1)	0.6(1.3)	<0.01
Outcome Measure			
Vaccine Administered	2601(14.9)	4776(16.4)	<0.01

conditions, were significantly associated with vaccine administration in the multivariable model.

In run charts comparing the two hospitals' vaccination rates, there was not a clear temporal association visually between implementation of the vaccine status banner and column interventions at each hospital and vaccination rates (Figure 8). By contrast, after initial implementation of the conditional discharge alert intervention at hospital A, the vaccination rate appears to increase relative to hospital B with a persistent improvement until implementation of the same intervention in hospital B.

Table 2: Factors Associated with influenza Vaccination Among Hospitalized Children

Factor	Odds Ratio (95%CI)	
	Crude	**Adjusted**
Intervention		
Intervention Order set	1.94 (1.84 - 2.04)	2.27 (2.13 - 2.41)
Intervention Conditional Alert	0.58 (0.55 - 0.61)	1.83 (1.57 - 2.12)
Intervention Banner and Column List	1.17 (1.09 - 1.25)	1.19 (1.03 - 1.36)
Hospital		
Hospital A EG	1 [Reference]	1 [Reference]
Hospital B SR	0.89 (0.85 - 0.94)	1.08 (1.02 - 1.15)
Hospital C HS	1.58 (1.42 - 1.75)	1.53 (1.37 - 1.72)
Flu Season		
2018-2019	1 [Reference]	1 [Reference]
2019 - 2020	2.47 (2.29 - 2.66)	1.64 (1.51 - 1.77)
2020 - 2021	1.76 (1.63 - 1.91)	0.89 (0.78 - 1.03)
2021 - 2022	0.93 (0.87 - 1.01)	0.34 (0.29 - 0.41)
Week of Influenza Season	0.95 (0.95 - 0.95)	0.94 (0.94 - 0.95)
Age		
6-23 Months	1 [Reference]	1 [Reference]
2-4 Years	1.1 (1.02 - 1.19)	1.05 (0.97 - 1.14)
5-12 Years	1.03 (0.96 - 1.11)	1.03 (0.96 - 1.11)
13-17 Years	0.88 (0.81 - 0.95)	0.91 (0.84 - 0.98)
18+ Years	1.03 (0.91 - 1.16)	1.08 (0.95 - 1.23)
Gender		
Male	1 [Reference]	1 [Reference]
Female	0.96 (0.92 - 1.01)	0.97 (0.92 - 1.03)
Race		
White	0.82 (0.78 - 0.86)	0.95 (0.82 - 1.09)
Black	1.11 (1.06 - 1.17)	0.95 (0.82 - 1.09)
Asian	1.24 (1.08 - 1.41)	1.38 (1.15 - 1.66)
Other	1.35 (0.99 - 1.8)	1.17 (0.83 - 1.61)

Factor	Odds Ratio (95%CI)	
	Crude	**Adjusted**
Unknown	1.25 (1.14 - 1.37)	1 (0.86 - 1.16)
Ethnicity		
Hispanic or Latino	1.41 (1.32 - 1.5)	1.41 (0.88 - 2.37)
Not Hispanic or Latino	0.71 (0.67 - 0.76)	0.86 (0.54 - 1.44)
Unknown	1.05 (0.64 - 1.64)	Not Included
Insurance		
Private	0.82 (0.78 - 0.87)	0.91 (0.78 - 1.06)
Public	1.2 (1.14 - 1.26)	0.96 (0.83 - 1.12)
Self-pay	1.09 (0.94 - 1.25)	Not Included
Number of complex chronic conditions	0.99 (0.97 - 1.01)	1.01 (0.99 - 1.03)
Admission and Discharge Characteristics		
Admission During Day Shift	1.01 (0.96 - 1.06)	1.01 (0.96 - 1.07)
Admission During Weekend	1.07 (1.01 - 1.14)	1.07 (1.01 - 1.14)
Discharge During Day Shift	1.19 (1.08 - 1.31)	1.27 (1.15 - 1.41)
Discharge During Weekend	0.88 (0.83 - 0.94)	0.86 (0.81 - 0.92)

Insurance category Self-pay and Ethnicity category Unknown not included in adjusted model owing to too few examples in those categories for coefficient estimation.

Figure 7: Vaccine Administrations by Influenza Season

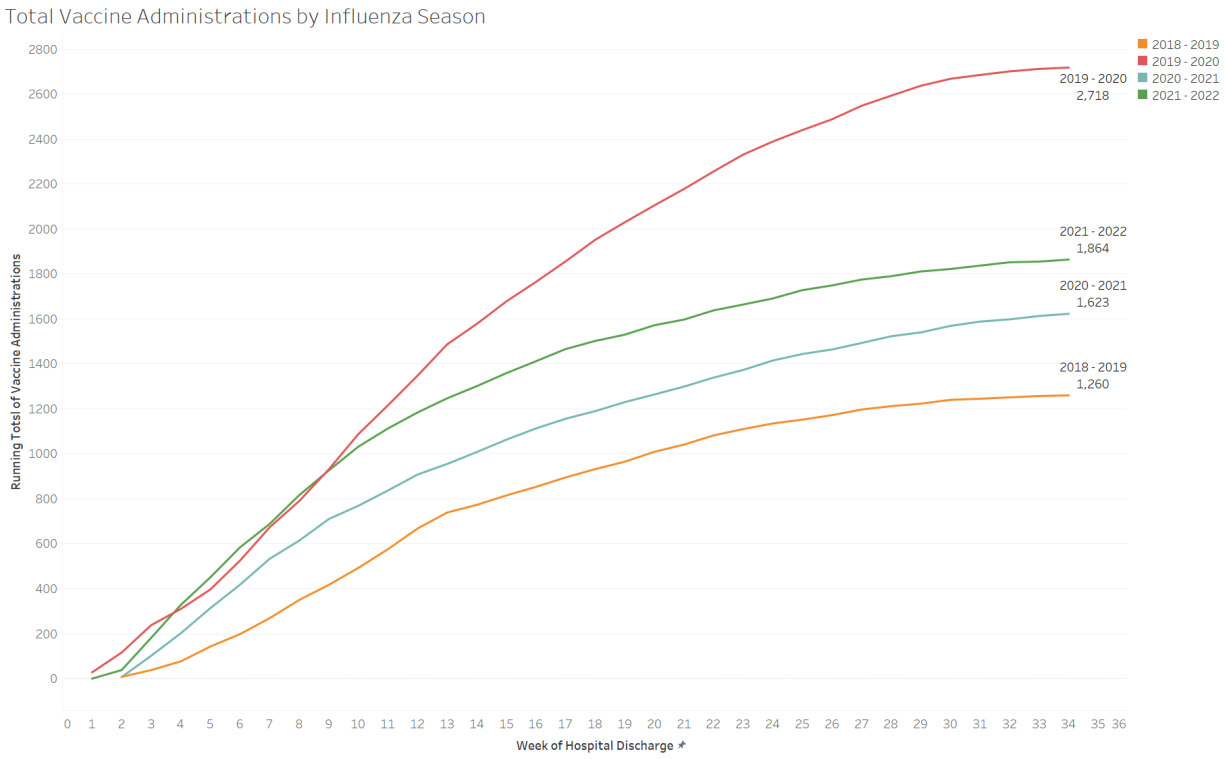
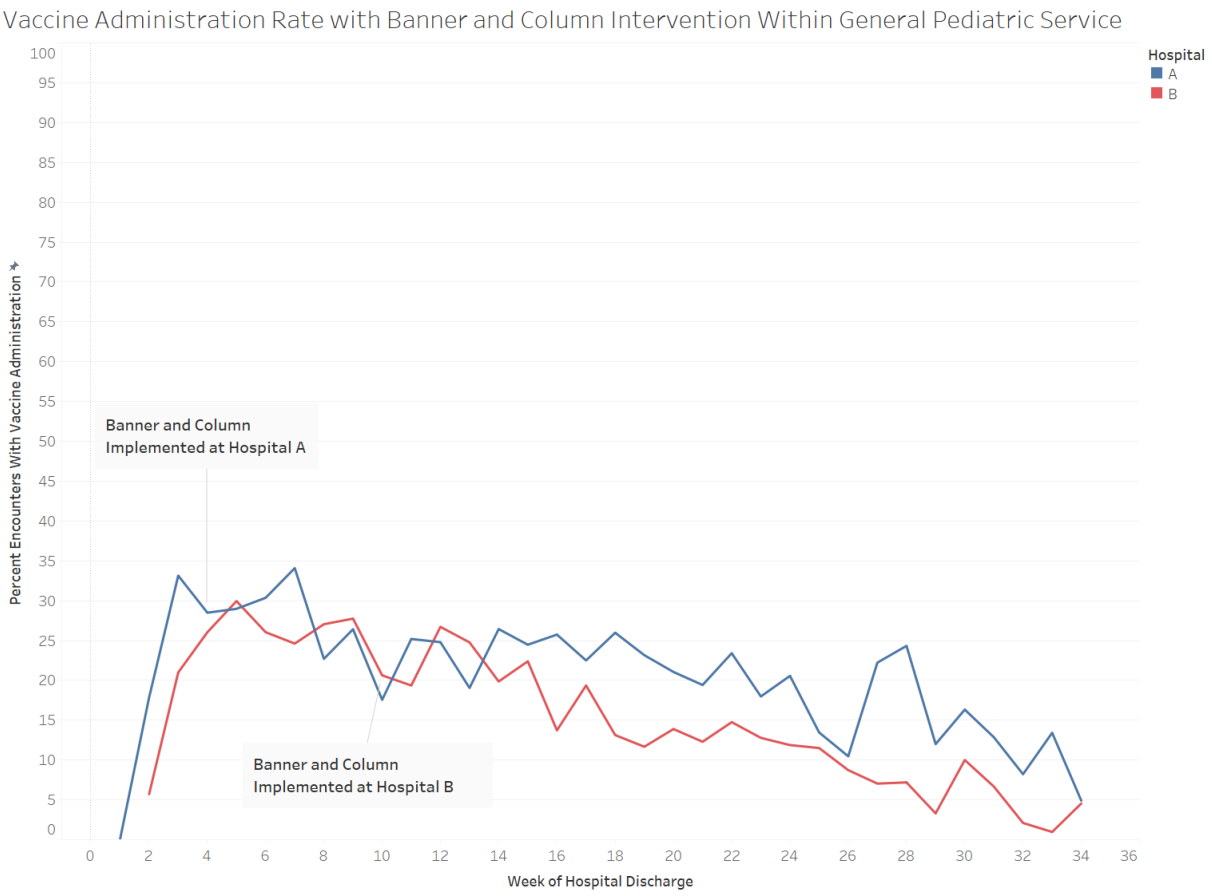


Figure 8: Vaccine Administrations Across a Single Season by Hospital Campus



Discussion

Our study demonstrated that three CDS interventions including (1) prechecked influenza vaccine orders in admission order sets, (2) vaccine status banners and patient list column, and (3) conditional discharge alert were significantly associated with improved influenza vaccine uptake in the pediatric inpatient setting. At the same time, the overall influenza vaccination rate waned significantly over time beginning in the 2020-2021 season, with the 2021-2022 season associated with an independent 66% reduction in the odds of vaccine administration compared to the baseline 2018-2019 season. This combination of factors may suggest that the reduction in QI support after the 2019-2020 season may have led to waning effectiveness of the CDS interventions. Alternatively, changing epidemiology of influenza infections including a remarkably mild season in 2020-2021 followed by changes in seasonality may have affected

provider attitudes toward the need for vaccination and appropriate timing. In addition, the climate of vaccine hesitancy worsened significantly over the course of the pandemic and into the 2020-2021 and especially the 2021-2022 influenza season.[4] Given that hospitalizations exposed to the CDS interventions had persistently higher vaccination rates than those that did not, our findings may represent ongoing CDS effectiveness that may even have blunted some of the decreases in vaccine administrations due to external factors.

Even with effective CDS, there remains a substantial proportion of hospitalized children eligible for influenza vaccine that do not receive influenza vaccine. Our CDS was designed to address gaps in clinician knowledge and support workflows to improve ordering through defaults, facilitate vaccine follow-up through status messages, and promote timely administration with nudges. However, it did not address provider or parental attitudes towards influenza vaccination in the hospital or provider burnout during the COVID-19 pandemic that may have reduced providers' willingness to engage in potentially confrontational conversations. Prior published studies to improve influenza vaccination in this setting have had wider varieties of implementation strategies such as audit and feedback, education of key stakeholders, or financial incentives. It remains unknown how these strategies may have been affected by the pandemic.

Conclusions

User-centered CDS involving tools targeting influenza vaccine ordering practices, awareness of vaccine status, and nudges for administration prior to discharge significantly improved the rates of influenza vaccination for eligible hospitalized children. However, over time the influenza vaccination rates in both the intervention and control groups fell significantly, which may be due to waning effectiveness of CDS and/or external factors such as changes in vaccine hesitancy, influenza burden, or provider attitudes. Despite the apparent effectiveness of these CDS systems, there remain substantial opportunities to improve influenza vaccination in hospitalized children who tend to be at higher risk of influenza-related morbidity and mortality due to greater

prevalence of chronic conditions and on average lower socioeconomic status and less outpatient support. Future studies that examine the combination of CDS with other implementation strategies addressing failure modes that are not targeted by CDS may yield greater overall benefits, reducing total influenza burden and supporting the health of this vulnerable population.

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List of Publications and Products

Publications

1. Orenstein EW, ElSayed-Ali O, Kandaswamy S, Masterson E, Blanco R, Shah P, Lantis P, Kolwaite A, Dawson TE, Ray E, Bryant C, Iyer S, Shane AL, Jernigan S. Evaluation of a Clinical Decision Support Strategy to Increase Seasonal Influenza Vaccination Among Hospitalized Children Before Inpatient Discharge. JAMA Network Open. 2021;4(7):e2117809. doi: 10. 1001/jamanetworkopen. 2021. 17809.
2. Kandaswamy S, Masterson E, Blanco R, Shah P, Lantis P, Iyer S, Shane E, Jernigan S, Orenstein EW. Barriers to seasonal influenza vaccine uptake in a pediatric inpatient healthcare setting after implementation of clinical decision support. Stud Health Technol Inform. 2022; 290:452-456. doi: 10.3233/SHTI220116.

National Abstract Presentations

1. Elsayed-Ali O, Orenstein EW, Kandaswamy S, Jernigan S, Shane A, Masterson E, Lantis P, Iyer S, Shah P, Blanco R. A Clinical Decision Support Intervention to Improve Inpatient Pediatric Influenza Vaccination. Accepted for poster presentation at the 6th Decennial International Conference on Healthcare Associated Infections of the Society for Healthcare Epidemiology of America, Atlanta, GA. March, 2020 (cancelled due to the COVID-19 pandemic).
2. Elsayed-Ali O, Kandaswamy S, Shane A, Jernigan S, Lantis P, Masterson E, Shah P, Blanco R, Iyer S, Orenstein E. A Clinical Decision Support Intervention to Improve Inpatient Pediatric Influenza Vaccination. Accepted for oral poster presentation at the Pediatric Academic Societies meeting, Philadelphia, PA. May 2020 (cancelled due to the COVID-19 pandemic).
3. Shah P, Blanco R, Orenstein E, Jernigan S, Shane E, Elsayed-Ali O, Morris CR, Masterson E, Kandaswamy S, Thummel H, Iyer S. Promoting Influenza Vaccine Administration in the Pediatric Emergency Department. Poster presentation at the American Academy of Pediatrics National Conference & Exhibition, October 2020 (virtual).
4. Elsayed-Ali O, Kandaswamy S, Shane A, Jernigan S, Lantis P, Masterson E, Shah P, Blanco R, Iyer S, Orenstein E. Improving Inpatient Pediatric Influenza Vaccination using a Clinical Decision Support Intervention. Accepted for podium presentation at the American Medical Informatics Association Annual Symposium, November 2020 (virtual).
5. Orenstein E, Chaparro J, Webber E, Muthu N. Clinical Decision Support for Health Maintenance Interventions in Acute Care Settings: Three Approaches to Promoting

Influenza Vaccine. Accepted for panel presentation at the American Medical Informatics Association Annual Symposium, November 2020 (virtual).

Technologies

Complex CDS in Epic Systems© with proven efficacy at increasing influenza vaccination rates in acute care settings including:

(1) Nursing documentation facilitating presumptive counseling for influenza vaccine, adapted for inpatient and ED settings.
(2) Dynamic default-checked influenza vaccine order populating order sets for children meeting eligibility criteria that is easily scaled across order sets.
(3) Influenza vaccine alert adapted for FastTrack and related Urgent Care settings.
(4) Vaccine status banner and patient list columns.
(5) Novel alert at discharge for patients with “hanging” influenza vaccine orders to encourage implementation.

Other Products

Data

- Robust dataset documenting influenza vaccine outcomes and risk factors.
- Qualitative data from user interviews and EHR documentation on barriers and facilitators of influenza vaccine in acute care settings.

Educational aids

- A novel tip sheet “How to talk to families about influenza vaccine” detailing evidence-based approaches to vaccine counseling, integrated into influenza vaccine orders for “Just In Time” education at the bedside.