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A Cluster Randomized Controlled Trial to Improve Influenza and Tdap Vaccination Rates for Pregnant Women

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Abstract

Introduction: We evaluated the impact of a provider and nurse-based intervention on influenza and Tdap vaccination rates among pregnant women.
Methods: The VAX-MOM trial was a 2-arm cluster randomized clinical trial conducted across 4 health systems (14 obstetric practices in Rochester, NY, and 13 in Los Angeles, CA), from April 2021 to June 2022. Practices were randomized to receive provider and nurse training via online modules (covering influenza and pertussis infections, vaccination, and workflow changes, such as presumptive vaccine recommendations) or standard care. Co-primary outcomes were influenza and Tdap vaccination rates for women delivering live births during the intervention. Analyses adjusted for clustering within practices.
Results: The study included 5992 and 6768 women eligible for Tdap vaccination, and 4609 and 5294 women eligible for influenza vaccination (intervention and control practices, respectively). Influenza vaccination rates declined by 5% in the intervention group (57% to 52%) and by 10% in the control group (57% to 47%). Tdap vaccination rates increased by 3% in both groups (67% to 70% in intervention; 72% to 75% in control). Adjusted analyses showed influenza vaccination rates were 8% higher in intervention practices (aRR 1.08, 95% CI [1.00, 1.15], $p = 0.038$; not significant given the $p < 0.025$ cutoff for 2 outcomes). Tdap rates showed no significant difference. Post-hoc analysis excluding one minimally engaged system revealed influenza vaccination rates were 13% higher in intervention practices (aRR 1.13, 95% CI [1.06, 1.19], $p < 0.001$).
Conclusion: Provider and nurse training improved influenza vaccination rates but did not significantly affect Tdap coverage in engaged practices.

Keywords: vaccination, influenza vaccine, Tdap, communication

Introduction

Pregnant women face higher risks of severe influenza complications, including hospitalization and death, compared with nonpregnant women.[1,2] Influenza during pregnancy is associated with increased adverse outcomes, including preterm birth and stillbirth.[2] Infants <6 months old are at a higher risk for influenza complications that may result in hospitalization compared with other age groups.[1] Maternal influenza vaccination is associated with a 40%

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reduction in influenza-associated hospitalization for pregnant women[3] and a 34% reduction in infant hospitalizations.[4]

From 1990 to 2022, infants under 1 year of age experienced the highest annual incidence of pertussis and were at the greatest risk for severe disease and mortality.[5] Maternal vaccination with tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis vaccine (Tdap) is 91% effective in protecting infants during their first 2 months of life.[6]

To reduce both influenza and pertussis morbidity, the Advisory Committee on Immunization Practices recommends that pregnant women receive an annual influenza vaccine (during any trimester)[7] and a Tdap vaccine during each pregnancy,[8] administered early in the 27–36 weeks of gestation window. Nonetheless, in 2022–23, only 47% received the influenza vaccine and only 55% received a Tdap during pregnancy.[9]

Our previous interviews[10] and surveys[11] evaluated office practice related to vaccination. While providers often used office system prompts, they rarely implemented standing orders, distributed patient educational materials, had vaccine champions, or measured vaccination rates. Barriers included patient hesitancy, suboptimal practice workflows, and insufficient emphasis on vaccination by providers and staff. These challenges indicated the need for a multi-component intervention, as recommended by the Community Guide.[12] Therefore, we aimed to assess the impact of a multi-component, scalable intervention involving providers and nurses on influenza and Tdap vaccination rates during pregnancy.

Methods

Study design and setting

The VAX-MOM trial was a 2-arm cluster randomized clinical trial in four health systems which included 14 obstetrics-gynecology (OB) practices in Rochester, NY and 13 in Los Angeles, CA from 4/1/2021–6/30/2022. Baseline study phases were approved by local Institutional Review Boards (IRBs), while the intervention phase was approved using the single IRB process with the University of Rochester acting as the IRB of record. Electronic health record (EHR) data were obtained via approved waivers of consent and HIPAA authorization.

Participants

We recruited practices in four health systems (two in Rochester and two in Los Angeles). Practice inclusion criteria were (1) being an obstetric practice within the health system, (2) stocking influenza and Tdap vaccines in the practice, (3) not serving as a primary training site for obstetric residents, and (4) being open for >1 year (for baseline vaccination rates). Practices with significant provider and/or nurse overlap were combined to represent one practice because the practice was the randomization unit.

Health systems within each state were chosen because their size allowed for ample patient sampling and they provided geographic and socio-economic diversity (e.g., insurance status, race/ethnicity, rural versus urban). Obstetric chairpersons at each health system agreed to participate and provided an email contact for each practice's medical director.

Medical directors identified one or more vaccine champions (provider, nurse, or both) within their practices. Participating providers could receive Maintenance of Certification quality improvement credit, and providers and nurses completing online training could receive continuing education credit. Vaccine champions received $5 for completing each Plan-Do-Study-Act (PDSA) cycle and $5 for each Practice Time Cost Survey for each of 12 intervention months (total $120). One health system required manual chart review (rather than vaccination data from automated EHR download), and vaccine champions in that system were paid $20 for each monthly review.

Vaccine champions disseminated the learning modules, fielded study intervention questions, acted as an ongoing liaison between study staff and site personnel, and helped schedule an introductory meeting with each practice at which study staff presented a study overview.

All pregnant women within each practice were included who had a live birth between 10/1/21 and 6/30/22 for influenza vaccination and 7/1/21 and 6/30/22 for Tdap vaccination, since influenza vaccination is given seasonally and Tdap is recommended in each pregnancy throughout the year.

Based on national influenza and Tdap vaccination rates, adjusting for clustering of patients in practices, and assuming an intraclass correlation of 1% (consistent with previous work),[13] we planned for a sample size of 5,000 pregnant women organized into 16 practices per study arm, which provided >80% power to detect a 6.3 percentage point increase in vaccination rates between intervention and control arms. This assumed a test-level alpha of 0.025, since we were examining two outcomes, influenza and Tdap vaccination.

Randomization

Practices were randomized within health systems. Per protocol, we performed a covariate-constrained randomization based on practice size and baseline influenza and Tdap rates in System 1 and System 2. Due to staff and provider overlap within System 3, we combined two practices in each arm and allocated the two combined practices by a simple coin flip. In System 4, we performed a covariate-constrained randomization based on practice size alone since baseline vaccination rates were not available. Participating practices and investigators were not blinded due to the intervention's nature. The trial included 12 intervention and 15 control practices (Fig. 1), resulting in >5,000 women per study arm but <16 OB practices per arm due to overlap of nursing and providers at 4 sites in System 2.

Intervention

In intervention practices, we implemented provider and nurse training *via* online interactive modules (45 minutes overall) which reviewed influenza and pertussis epidemiology, vaccine effectiveness and safety in pregnancy, and provided answers to common patient questions (https://share.articulate.com/0Rl0Svs9EvbgkaAv_wliO). The training recommended that nurses and providers: identify a vaccine champion, assess vaccine status, use a strong recommendation with presumptive language to recommend influenza/Tdap vaccine ((i.e., 'you are due for your flu vaccine' rather than 'would you like a flu vaccine?'), offer the vaccine if previously declined, and use provider prompts or standing orders. Thus, the training module recommended practices implement multiple changes simultaneously. We sent the training module weblink to 134 providers (physicians, nurse practitioners, physician assistants and

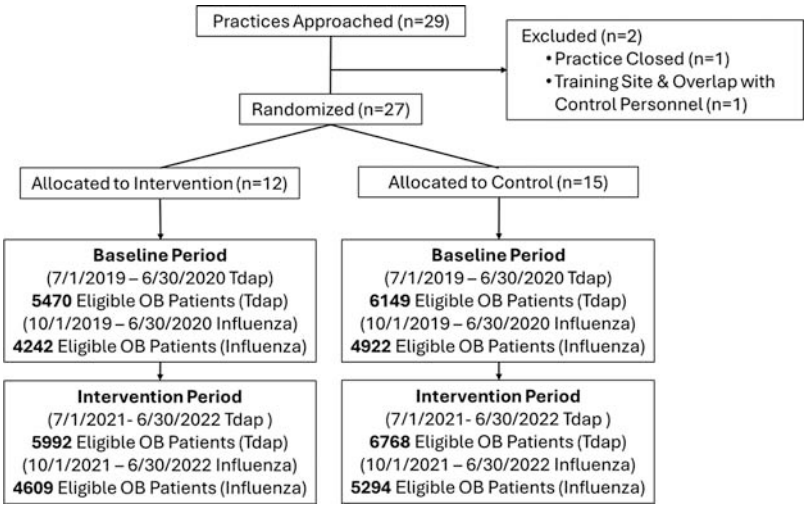

FIG. 1. CONSORT Diagram.

certified nurse midwives) and 147 staff (nurses, medical assistants, and front desk staff) between May and July 2021. In September 2021, at influenza vaccination season's start, we sent the link to a 15-minute 'influenza vaccination booster module' to all intervention practice providers and nurses; this reviewed influenza severity, vaccine safety and effectiveness and summarized answers to common questions.

We met with each practice *via* Zoom to introduce the study and present them with their baseline vaccination rates. We explained the concept of implementing and monitoring small monthly changes in communication and practice workflow as PDSA cycles. At that Zoom meeting we solicited ideas for each practice's first PDSA cycle. We later delivered posters promoting vaccination to hang within each practice and encouraged use of patient education handouts for the first obstetric visit. Vaccine champions were encouraged to meet with their entire practice team to develop and implement PDSA cycles. Practice vaccine champions were asked to complete monthly PDSA surveys to describe any office changes made during the past month.

Each month, we reported practice-specific vaccination rates to vaccine champions for dissemination to and discussion with their practice team. The reports showed the percentage of maternal influenza and pertussis (Tdap) vaccination for women with a live birth each month (Tdap given any time and within the 27–36-week window).

Control practices received standard of care, with no study-related interventions.

Measures

The primary outcome measures were influenza and Tdap vaccination rates for women who delivered a live birth during the intervention period (10/1/2021–6/30/2022 for influenza; 07/1/2021–6/30/2022 for Tdap). We adjusted for practice-level vaccination rates during the pre-COVID-19 baseline period (influenza and Tdap vaccination rates within each practice from 10/1/2019–6/30/2020 and 7/1/2019–6/30/2020, respectively) to improve power. For comparison, we used the year before the COVID-19 pandemic (i.e., 7/1/2019–6/30/2020), rather than the pandemic year, due to pandemic-related changes in visit patterns.

We evaluated intervention effects within subgroups defined by four covariates obtained from EHR data: race, a social construct, to relate the intervention to national context regarding demographic and social characteristics,[14] insurance status, parity (first pregnancy = nulliparous versus multiparous), and smoking status.

Process Metrics: We measured the number (percent) of personnel who completed the module by practice and health system, practice meeting attendance at Zoom meetings, vaccine champion turnover, and vaccine champion engagement. We categorized low engagement as: ≤50% of PDSA cycle surveys returned, ≤50% of providers and nurses completed modules, or if the vaccine champion did not complete the initial module.

Statistical analyses

We employed intent-to-treat analyses using robust Poisson mixed models with practice random effects to estimate the interventions' effect on vaccination rates for pregnant women, adjusting for clustering within practice. We adjusted models for practice-level baseline vaccination rate and health system. We analyzed by baseline rates since clinic randomization was stratified by health system to assess the effect of differential engagement and balanced by baseline vaccination rates. Exploratory analyses evaluated intervention effects by patient characteristics by fitting the same models within subgroups. We also performed a post-hoc analysis without one health system that participated minimally in the intervention. Analyses were performed using R v.4.1.0 (http://www.r-project.org/).

Results

Study participants

We randomized 27 practices,12 in the intervention group (CONSORT diagram, Fig. 1). Intervention practices had 134 providers and 147 staff; control practices had 123 providers and 111 staff (Table 1). Intervention and control groups were similar by publicly insured women (49.8% intervention, 46.9% control) and baseline influenza vaccination rates (57.0% intervention, 56.7% control). The racial/ethnic distribution was: 'other race' (37.1%), White (30.1%), Black (15.4%), and Hispanic (9.9%). Respectively, 4,609 and 5,294 women delivered live births in intervention and

Table 1. Characteristics of Practices and Women Randomized During Intervention Period (July 2021–June 2022)

Characteristic	*Overall*	*Intervention group*	*Control group*
Practices	27	12	15
Practice participants			
Providers	257	134	123
Nurses and other staff	258	147	111
Women eligible for influenza vaccine	9,903	4,609	5,294
Women eligible for Tdap vaccine (inclusive of those eligible for influenza vaccine)	12,760	5,992	6,768
Race/Ethnicity (Self-Reported)			
Asian	956 (7.5%)	430 (7.2%)	526 (7.8%)
Black	1,960 (15.4%)	694 (11.6%)	1,266 (18.7%)
Hispanic	1,268 (9.9%)	547 (9.1%)	721 (10.7%)
White	3,847 (30.1%)	1,831 (30.6%)	2,016 (29.8%)
Other	4,044 (31.7%)	2,134 (35.6%)	1,910 (28.2%)
Unknown	685 (5.4%)	356 (5.9%)	329 (4.9%)
Insurance			
Public	6,157 (48.3%)	2,985 (49.8%)	3,172 (46.9%)
Private	6,475 (50.7%)	2,960 (49.4%)	3,515 (51.9%)
Other	10 (0.1%)	2 (0.0%)	8 (0.1%)
Unknown	118 (0.9%)	45 (0.8%)	73 (1.1%)
Tobacco use			
Current	398 (3.1%)	207 (3.5%)	191 (2.8%)
Previous	1,236 (9.7%)	590 (9.8%)	646 (9.5%)
Never	7,296 (57.2%)	3,611 (60.3%)	3,685 (54.4%)
Unknown	3,830 (30.0%)	1,584 (26.4%)	2,246 (33.2%)
Parity			
Multiparity	6,739 (52.8%)	3,209 (53.6%)	3,530 (52.2%)
Nulliparity	5,081 (39.8%)	2,339 (39.0%)	2,742 (40.5%)
Unknown	940 (7.4%)	444 (7.4%)	496 (7.3%)
Baseline influenza vaccination rate (%)*	56.9%	57.0%	56.7%
Baseline Tdap vaccination rate in window (27–36 weeks, %)**	69.8%	66.9%	72.5%
Baseline Tdap vaccination rate any time (%)**	75.9%	72.7%	78.7%

*Influenza vaccination baseline Oct 2019–June 2020, **Tdap baseline July 2019–June 2020.

control practices from October to June and were eligible for influenza vaccination; 5,992 and 6,768 women delivered live births in intervention and control practices from July to June and were eligible for Tdap vaccination.

Results by study group

Influenza vaccination rates declined by 5 percentage points in the intervention group (57–52%), and by 10 percentage points in the control group (from 57% to 47%, Table 2). Tdap vaccination rates in the 27–36-week window increased 3 percentage points in both groups (67–70% in intervention; 72%–75% in controls). Tdap vaccination rates anytime increased 3 percentage points in the intervention group (73%–76%) and 2 percentage points in the control group (79%–81%).

When adjusting for baseline rates in a regression model (Table 3), influenza vaccination rates were 8% higher among intervention than control practices, which was not significant

Table 2. Baseline (July 2019–June 2020) and Intervention Period (July 2021–June 2022) Influenza and Tdap Vaccination Rates for Pregnant Women with a Live Birth in Randomized Practices

Vaccine	*Group*	*% Vaccinated during baseline period*	*% Vaccinated during intervention period*	*Delta (intervention %–baseline %)*
Influenza vaccination rate results*				
	Intervention	57%	52%	−5%
	Control	57%	47%	−10%
Tdap vaccination (27–36-Weeks Gestation) rate results				
	Intervention	67%	70%	3%
	Control	72%	75%	3%
Tdap vaccination (Any Time) rate results				
	Intervention	73%	76%	3%
	Control	79%	81%	2%

*Influenza vaccination baseline Oct 2019–June 2020.

Table 3. Overall Effects of Intervention on Influenza and Tdap Vaccination Rates, Regression Model Adjusting for Baseline Rate, All Systems and Without System 4[a]

	All 4 systems		*Without system 4**	
Effect	*aRR (95% CI)*	p	*aRR (95% CI)*	p
Influenza vaccination, adjusting for baseline rate				
Intervention v. Control	1.08 (1.00, 1.15)	0.038	1.13 (1.06, 1.19)	<0.001*
Tdap (27–36-Weeks) Model 1. adjusting for baseline rate				
Intervention v. Control	0.95 (0.89, 1.01)	0.114	1.03 (1.00, 1.06)	0.054
Tdap (Any Time) Model 1. adjusting for baseline rate				
Intervention v. Control	0.98 (0.92, 1.03)	0.430	1.02 (1.00, 1.03)	0.023*

*Indicates statistical significance at 2.5% level.
[a]Post-hoc analyses performed without system 4 due to lack of active participation in the intervention.

after adjustment for multiple comparisons with two outcomes [aRR 1.08, 95% CI (1.00, 1.15), $p = 0.038$]. The baseline rate was a strong predictor of rates post-intervention (aRR 3.17, 95% CI (1.74, 5.78)). Tdap vaccination rates within the 27–36-week window and at any time were not significantly different between intervention and control groups.

In a post-hoc analysis without System 4 which had minimal engagement in the intervention, influenza vaccination rates were 13% higher among intervention than control practices (aRR, 1.13, 95% CI (1.06, 1.19), $p < 0.001$). Tdap vaccination within the 27–36-week window was not significant, but Tdap any time rates increased by 2% [aRR 1.02 (1.00, 1.03), $p = 0.023$].

Results stratified by health system

In a regression model accounting for health system interactions, practices in two systems had 12% higher influenza vaccination rates compared with control practices (Table 4), Tdap vaccination rates during 27–36-weeks gestation improved by 10% in one health system, and Tdap vaccination rates anytime improved by 2–3% in two health systems. Health System 4's Tdap rates significantly worsened in both study groups.

Table 4. Effect of Intervention on Influenza and Tdap Vaccination Rates with Health System Interactions

Effect/System	*aRR (95% CI)*	p
Influenza vaccination ($p = 0.002$)		
System		
1	1.14 (0.94, 1.38)	0.171
2	1.12 (1.11, 1.14)	<0.001*
3	1.12 (1.03, 1.21)	0.005*
4	0.97 (0.90, 1.04)	0.433
Tdap vaccination (27–36-Weeks) ($p < 0.001$)		
System		
1	1.00 (0.96, 1.04)	0.972
2	1.10 (1.06, 1.13)	<0.001*
3	1.00 (0.96, 1.05)	0.904
4	0.80 (0.73, 0.87)	<0.001*
Tdap vaccination (Any Time) ($p < 0.001$)		
Intervention v. Control	0.96 (0.91, 1.02)	0.209
1	0.98 (0.95, 1.02)	0.387
2	1.03 (1.00, 1.05)	0.022*
3	1.02 (1.00, 1.05)	0.019*
4	0.87 (0.80, 0.94)	<0.001*

*Indicates statistical significance at 2.5% level.

Results by patient characteristics

Compared to controls, intervention practices showed a statistically significant improvement in influenza vaccination rates for Black (30%) and White (10%) women (Appendix Table A1). Influenza vaccination rates for privately insured women and multiparous women were also significantly higher in intervention practices. No differences in intervention impact were noted by smoking history, which was not well captured.

Provider and nurse engagement

Four practices had 71–89% of providers and nurses complete the core module, five had 42–68%, and three had ≤25% completion (all in System 4). In three practices (two in System 4), the vaccine champions did not complete the core module. The influenza booster module had 0–91% (mean 33%) completion. Practice meeting attendance ranged from 41% to100% (mean 72%). Five practices had low engagement. One health system (System 4) had three of four practices with low engagement; one of these had no engagement (Appendix Table A2).

PDSA cycle reports

Interventions reported by practices are shown in Appendix Figure A1. The most used communication interventions were bringing up vaccination again with the patient at a subsequent visit even if they declined previously, presumptive language use, and providing patient education. The most used workflow changes were pre-visit planning in an EHR note, using a checklist, and documenting vaccines received elsewhere.

Discussion

This multi-component intervention in obstetric offices appeared to raise influenza vaccination rates compared with control sites by 8%, although not a significant result given a p value cutoff of 0.025. Excluding the health system with minimal participation, influenza vaccination rates increased significantly by 13% in intervention versus control practices. Tdap vaccination rates, high at baseline in participating practices (with rates more than 10% higher than national rates), were unaffected overall. Within two health systems, the

intervention raised influenza vaccination rates significantly by 12%, and within one health system Tdap vaccination rates within the 27–36-week window of gestation increased by 10%. In Health System 4, with low engagement, the intervention had no effect, and Tdap rates declined.

Nationally, influenza and Tdap vaccination rates during pregnancy declined following the COVID-19 pandemic; 47% of pregnant women received influenza vaccine in 2022, compared with 61% in 2019.[15] Tdap rates declined less so, with 55% receiving Tdap in 2022, compared with 57% in 2019. Our multi-component intervention was successful in maintaining vaccination rates close to the pre-pandemic level for influenza.[16]

Our study provides insights into helpful interventions to increase vaccination coverage for pregnant women. A providers' recommendation has been strongly associated with maternal vaccine uptake.[9] Our intervention trained providers and nurses to use presumptive language when recommending the influenza and Tdap vaccines, a method shown to be effective for increasing HPV[17] and early childhood vaccination rates.[18] This approach normalizes vaccination as a part of prenatal care and may suffice for acceptance by some individuals. Some women may have questions about vaccine safety or side effects during pregnancy.[19,20] Increasing nurses' and providers' confidence in addressing these concerns may have impacted vaccination rates.

For the 25% of women nationally who report being very hesitant about influenza vaccination during pregnancy,[9] more intensive interventions may be needed. In this study, the most applied intervention was repeating the recommendation to former vaccine refusers, which frequently led to vaccination. Thus, using presumptive language, addressing questions about vaccine effectiveness and safety, and bringing up vaccination at subsequent visits for women who previously refused are three helpful communication strategies to optimize vaccination during pregnancy.

Our intervention had a robust impact on influenza vaccination rates for Black women (an increase compared with control practices of 30%). In past studies, Black women reported a lower rate of being recommended or offered the vaccine.[21] Our intervention helped systematize workflow to increase the offering of influenza vaccine, potentially building trust and addressing individuals' specific concerns.

Stocking vaccines in the provider's office is associated with higher vaccination rates.[22] All participating practices stocked influenza and Tdap vaccines in this study. Pregnant women frequently visit obstetric practices, and provider recommendations paired with vaccine availability at the visit can improve uptake.[20,23]

This intervention relied on the engagement of vaccine champions, who were nurses or obstetric physicians. Practices had variable participation, with low engagement noted in five practices. One health system had very low engagement, but all were included in this pragmatic trial. The other three systems had overall better engagement and improved vaccination rates compared with controls. In these practices, vaccine champions were responsive, whereas low engagement practices had substantial turnover or low participation among their vaccine champions. A prior implementation study showed that attributes of successful obstetric provider champions included ownership of a problem, physical presence, and a participative leadership style.[24] Attributes specific to vaccine champions associated with effectiveness include being formally appointed as a champion, working extremely closely with providers, and using a high number of implementation strategies to improve vaccination rates.[25]

Obstetric practices are busy, with many competing demands. However, feedback on vaccination rates is feasible within most EHRs and consequently sustainable. Online training modules on communication and workflow can be integrated into new staff and provider training. The modules can reinforce the use of presumptive language and the importance of vaccinating pregnant women to help protect their infants, as well as the practice of offering vaccines repeatedly if faced with hesitancy.

Our study has several strengths. We included many practices in four health systems in two states in a cluster randomized design. Vaccination rates were measured from each practice's EHR. This was a pragmatic study in busy practices, and the intervention is scalable and sustainable, with training done using online modules.

Study limitations include the potential for increased Type II errors (the failure to detect actual differences) due to the use of the Bonferroni correction (dividing our alpha by half). Also, practice changes were measured by practice champions' reports and may not reflect all provider and staff experience within a practice. The practices had the support of their health systems to participate, which may not be generalizable to other locations. In addition, women who had preterm birth <27 weeks were not eligible for Tdap.

We conclude that this cluster randomized trial of obstetric practices, online communication, and workflow training (using presumptive language, offering vaccines if declined previously, and training nurses to answer questions) positively affected influenza vaccination rates and increased Tdap rates in some practices. The intervention could be scalable for practices ready to make changes in communication and workflow.

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Authors' Contributions

All authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the article.

Author Disclosure Statement

No competing financial interests exist.

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(*Appendix follows* →)

Appendix

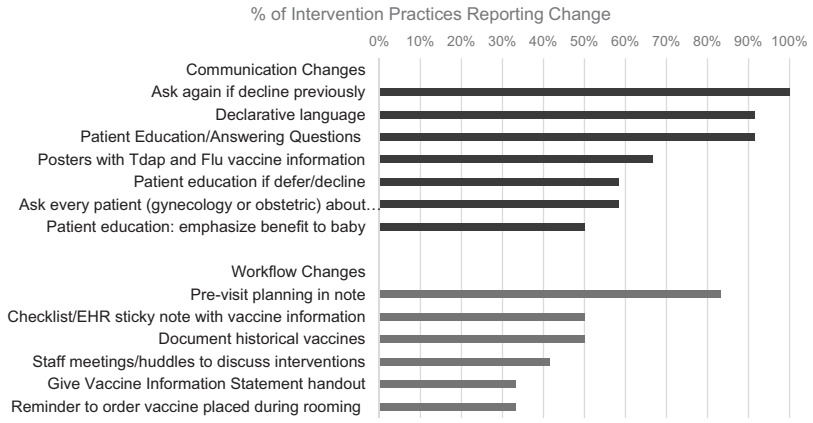

FIG. A1. Percent of Intervention Practices that Reported Implementing Various Types of Quality Improvement Interventions.

Table A1. Effect of Intervention on Influenza Vaccination Rates by Covariates[a]

	All 4 systems		*Without system 4**	
Characteristic	*RR (95% CI)*	p	*RR (95% CI)*	p
Race/Ethnicity				
Asian	0.96 (0.81, 1.15)	0.681	0.97 (0.81, 1.16)	0.741
Black	1.30 (1.08, 1.56)	0.006*	1.22 (0.99, 1.52)	0.065
Hispanic	1.15 (0.97, 1.36)	0.106	1.15 (0.97, 1.36)	0.106
White	1.10 (1.00, 1.21)	0.043	1.12 (1.02, 1.23)	0.021*
Payor				
Public	1.05 (0.95, 1.15)	0.325	1.10 (0.94, 1.28)	0.258
Private	1.11 (1.03, 1.19)	0.005*	1.13 (1.05, 1.22)	0.001*
Tobacco user				
Current	1.49 (1.00, 2.24)	0.052	1.45 (<0.01, >99)	0.976
Previous	1.06 (0.87, 1.28)	0.573	1.17 (0.90, 1.52)	0.246
Never	1.08 (1.00, 1.16)	0.050	1.11 (1.01, 1.22)	0.038
Parity				
Multiparity	1.09 (1.01, 1.18)	0.022*	1.13 (1.02, 1.25)	0.014*
Nulliparity*	1.07 (0.98, 1.17)	0.124	1.11 (1.02, 1.22)	0.023*

[a]Post-hoc analyses performed without system 4 due to lack of active participation in the intervention.
*$p < 0.05$.

Table A2. Site Engagement and Influenza Vaccination

Health system	*Intervention site*	*Site module completion*	*VC module completion (Y/N or #/total)*	*VC PDSA completion (12 maximum)*	*Overall engagement (low or high)*	*aRR (95% CI) of influenza vaccination*
1	A	82%	Y	12	High	1.14 (0.94, 1.38)
	B	71%			High	
	C	89%	Y	12	High	
	D	80%			High	
	E	60%	N	10	Low	
	F	68%	Y	8	High	
2	A	63%	Y	12	High	1.12 (1.11, 1.14)
	B		Y	12	High	
	C		Y	12	High	
	D		Y	12	High	
3	A	60%	1/1	12	High	1.12 (1.03, 1.21)
	B	42%	2/2	4	Low	
4	A	0%	0/2	0	Low	0.97 (0.90, 1.04)
	B	25%	2/3	6	Low	
	C	16%	0/4	1	Low	
	D	78%	1/1	12	High	

System 1 sites A&B and C&D each had 1 vaccine champion.
VC, vaccine champion.