The Development Testing and Implementation of the 4 Pillars™ Practice Transformation Program for Immunization: Achieving Public Health Outcomes Through Primary Care Quality Improvement

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Abstract

The 4 Pillars™ Practice Transformation Program for Immunization is an evidence-based quality improvement program to improve immunization outcomes in primary care. The intervention strategies, implementation methods and the 4 Pillars™ of Convenience and Access, Patient Communication, Enhanced Vaccination Systems, and Motivation were informed by theoretical frameworks from the sciences of medicine, public health, systems and implementation and the social ecological model. The program was most-recently deployed in three different settings; a multi-center cluster-randomized clinical trial, a continuing medical education performance-in-practice module, and a quality improvement initiative in a regional community medicine health care organization.

In clinical trials, the program demonstrated efficacy to improve increased uptake of seasonal influenza vaccine in children; meningococcal and Tdap vaccines and HPV initiation and completion in adolescents; seasonal influenza, pneumococcal, and pertussis vaccines in adults; and pneumococcal vaccines in older adults. Population-level cost-effectiveness models of the data report that the program was a good value with incremental cost-effectiveness ratios of $4937 within American Board of Family Medicine physicians seeking continuing education credit and $31,700 as a clinical trial per quality adjusted life year gained. An analysis of the efficacy of the program as conducted in 63 practices of a primary care division of a large regional health

organization was inconclusive failing to replicate the results observed in clinical trials. Secular trends, data availability, and methodological limitations interfered with the fidelity of the intervention which led to sub-optimal results.

Public Health Significance - System limitations in practice of health care were observed. Nearly all domains of medical quality improvement would benefit from substantial changes to the user experience at the point of care, health data systems interoperability, and the availability of consistent patient-level data for epidemiologic research and the development of simulation models of health systems and health behavior dynamics. Translating a complex intervention from a laboratory controlled clinical trial to an organization-directed quality improvement program is a significant challenge in public health. This process of scaling mirrors the barriers of influencing behavior in nested social ecological levels. Consequently, the 4 Pillars™ can provide guidance to improve efficacy of future public health programs.

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Preface

This manuscript covers nearly a decade of work to scale an interesting theoretical model of practice change in a physician's office to a rigorous framework for health-system-based quality improvement programs targeting public health outcomes. It would not have been possible without the dedication of Drs. Zimmerman and Nowalk who first conceived of the 4 Pillars™ during their study of immunization practices in primary care. I am profoundly grateful for their mentorship and guidance throughout the many phases of this project. The technical jargon and aloof professionalism of their technical writings do not convey the depth of their altruism and humility. Their influence on public health will inevitably extend beyond their scientific discoveries to the professionals who are blessed to serve with them. Likewise, I am equally thankful to the faculty of the Graduate School of Public Health and my advisory committee who have offered empathy, encouragement and critique whenever necessary. Finally, I am most thankful for my wife who has a seemingly endless supply of patience and enthusiasm whenever my determination has waned.

It would be impossible to acknowledge of all the individuals who made important contributions throughout this journey. There have been so many people who have given generously of their experience, time and resources with no expectations beyond the hope that they might make something better for someone else. My experience through every chapter of this epic has reinforced that the often-maligned institutions of government, healthcare and big pharma are actually staffed by some of the most caring, committed and compassionate professionals in the workforce. Our modern understanding of health, disease and treatment would not be possible without their tireless effort towards solving extraordinarily difficult problems. Now, more than ever, these entities will need to cooperate to translate individual health to population health.

Since before the discovery of farming, through the industrial revolution, and continuing into the information era, our species has demonstrated superior adaptability through technological innovation. As our global population continues to grow, new challenges are being revealed on an almost daily basis. If we are to have any hope of preventing apocalypse while working to colonize Mars, many new skills, techniques and philosophies will need to incubate in safe environments where they can be nurtured through intellectual germination. I am excited to be a part of this next cycle of agrarian evolution where ideas become the crops that nourish and enrich our civilization.

1.0 Immunization Quality Improvement in Primary Care Practices

Despite major advances in immunization science with the licensure of effective vaccines, they are often underused. To a clinician, the patient sitting in the exam room suffering from a disease seems far more compelling than all of the unseen, averted cases prevented by excellent care. Perhaps it is part of a healer's nature to focus on disease rather than on health. Health seems nebulous and precarious, while disease is concrete and measurable. Yet, one of the top ten achievements of modern medicine is immunization.(1)

Immunization is an exemplar of successful public health programming. In one of the greatest cooperative achievements of humankind, smallpox was declared globally eradicated a mere 200 years after the initial discovery of variolation. Given that this was accomplished during the infancy of modern epidemiologic surveillance techniques, vaccine manufacturing processes, and before the age of rapid international travel, our modern challenges to routine vaccination seem trivial compared with those faced by early vaccination pioneers.(2) By learning from experience and systematically building on success, the eradication of smallpox was just the beginning of mass prevention of infectious diseases. With the eradication of polio in sight, our global community has demonstrated that even the most obstinate barriers to immunization can be overcome.(3)

While global eradication of a virulent pathogen is a noble objective, the routine control of the cadre of less spectacular illnesses has an even greater ability to extend life. Between 1900 and 1997, average life expectance in the United States was extended by 29.2 years, largely due to the reduction of mortality from infectious diseases in children under 5 years of age.(4). Even mediocre success in controlling influenza (the most devious of vaccine preventable diseases) has resulted in the estimated prevention of up to 6.6 million cases and 79,000 hospitalizations *per year* in the

United States between 2005 and 2013.(5) Despite these obvious public health triumphs, the US vaccination program is still far from perfect.

Vaccination opportunities still exist and with varying degrees of severity. In Healthy People 2020(6), the CDC reports vaccination coverage rates are below target for: ≥4 doses of diphtheria, tetanus, and acellular pertussis vaccine (DTaP), the full series of Haemophilus influenzae type b (Hib) vaccine, hepatitis B (HepB) birth dose, ≥4 doses pneumococcal conjugate vaccine (PCV), ≥2 doses of Hepatitis A, the full series of rotavirus vaccine, and the combined vaccine series; (7) Human Papillomavirus (HPV) vaccine in adolescents; (8) and seasonal influenza vaccination. (5, 9) However, a more troubling observation than sub-par vaccine-specific rates is the systematically low rates of vaccination among entire demographics, particularly adults (10) and the underprivileged and vulnerable. (7) Improving universal vaccination coverage in the United States will certainly take resources, determination and effort. However, the example of global smallpox eradication, led by D.A. Henderson, demonstrates what is possible when unwavering conviction and steadfast tenacity are applied to the obstacles to improving vaccination rates.(11)

1.1 Theoretical Models Relevant to the US Immunization System

1.1.1 Social Context of Immunization Behavior

In comparison to other health behaviors, the behavior of vaccination is simple. For some vaccine preventable diseases (VPD), even a single inoculation is sufficient to provide lifelong protection. As compared to weight loss, smoking cessation or the maintenance of healthy levels of

physical activity, the binary decision associated with vaccination should be less difficult than avoiding the onslaught of temptations that threaten the daily confirmation of healthy lifestyle decisions. Therefore, it seems logical to focus considerable effort at the individual level to have patients say, “yes” to vaccination at the point of care. However, the application of individual-level theories, while important, is unlikely to drive results at a population level.

1.1.2 Immunization Services at a Societal Level

The social ecological model(12), as depicted in Figure 1 (13), defines a nested hierarchy of social-psychological influences that account for variances in behavior. For example, in an analysis of the uptake of the 2009 H1N1 influenza vaccine among United States adults, Kumar, Quinn, et al. (14) found that each social ecological level was a significant predictor of both intention and uptake. The variances in vaccine uptake were the individual level (53%), the interpersonal level (47%), the organizational level (34%), the community level (8%) and the public policy level (8%). In combination, all levels explained 65% of the variance in uptake which suggests that a systemic approach could achieve more than interventions targeting any single level.

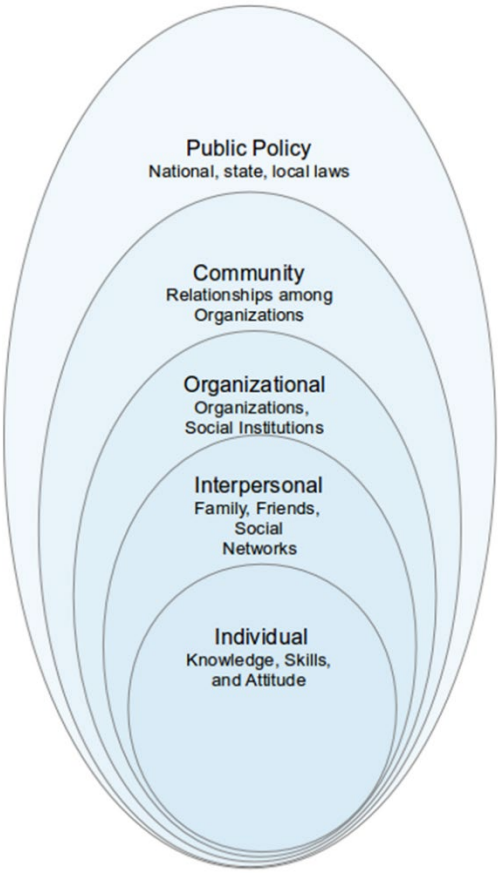

Figure 1 Socio-ecological model

Leveraging the multiplicative effects that come from multi-systems interventions is critical to maximizing the effectiveness of vaccination interventions. The results presented above, quantify the influence of each of the levels of the social ecological model. While 65% sounds like a high number, it actually means that the model can account for most of the reasons why participants did, or did not, receive the vaccine. What it does not report, however, is how many people did receive the vaccine. That figure is much less encouraging. The US Centers for Disease Control and Prevention (CDC) estimated that only 20.1% of US adults were vaccinated with the 2009 H1N1 influenza vaccine.(15) The 2009 H1N1 influenza pandemic is a frightening example of how far our public health system needs to advance to truly protect the population. If the 2009 pandemic

had been as virulent as the 1918 Spanish flu pandemic, a meager 20.1% coverage rate would have left millions of adults susceptible to a potentially deadly infection.

If the social ecological model can account for most of the variance in immunization behavior, then why are coverage levels lower than desired? First, the application of multi-level models, like the example above is an avant-garde approach to conceptualizing health outcomes. As evidenced by the corpus of immunization publication, a great deal of scientific effort has focused on the individual predictors of health behavior with decreasingly less rigorous scrutiny applied to the ascending intermediate social levels. The analysis from Kumar, Quinn, et al.(14) presented above mirrors this supposition. While it is possible that the ascending social strata are less predictive of individual behavior, it is also possible that the current extra-personal interventions are too feeble to produce a substantial effect. For example, our national vaccination plan includes some specific interventions in public policy, including publicly subsidized vaccinations and compulsory vaccination programs, but by largely excluding adults, those policies have been inconsistently applied to the population. Additionally, immunization interventions at the interpersonal level (like social marketing(16)), the organizational level (like employer mandated vaccination(17)), and at the community level (like pharmacist administration of vaccine(18)) are all fairly new efforts. For these reasons, future analyses of health behavior may find that the broader levels of the social ecological hierarchy will contribute an increasing greater proportion of influence.

In addition to the novelty of the simultaneous application of multi-level interventions, the second reason for sub-optimal outcomes is that the interdependencies among levels is not well understood. Acknowledging that immunization interventions need to target multiple levels of the social ecological hierarchy is good, intervening at multiple levels simultaneously is better, but still

difficult. To coordinate maximum impact on immunization rates, the entire US society (and, arguably, the global society) must be viewed as a complex dynamic system. The simplistic diagram of social ecological levels discretely nested like Russian dolls one inside another, ignores the tangled network of interdependencies woven within, between and among all of the levels of social organization.(19)

1.1.3 The Social Determinants of Health as a Framework for Immunization Services

The Commission on Social Determinants of Health was established in 2005 by the World Health Organization (WHO). This commission was charged with building a model of the social inputs to individual health. The resulting conceptual framework, the social determinants of health (SDH)(20), pictured in Figure 2, overcomes the limitations of the social ecological model by describing health as the result of a multi-level social structure that acts as a complex adaptive system. This framework is useful in planning and evaluating intervention strategies as potential leverage points can be examined within the system dynamics. This contextualization allows for the identification of unintended consequences resulting from non-obvious interactions among system variables.

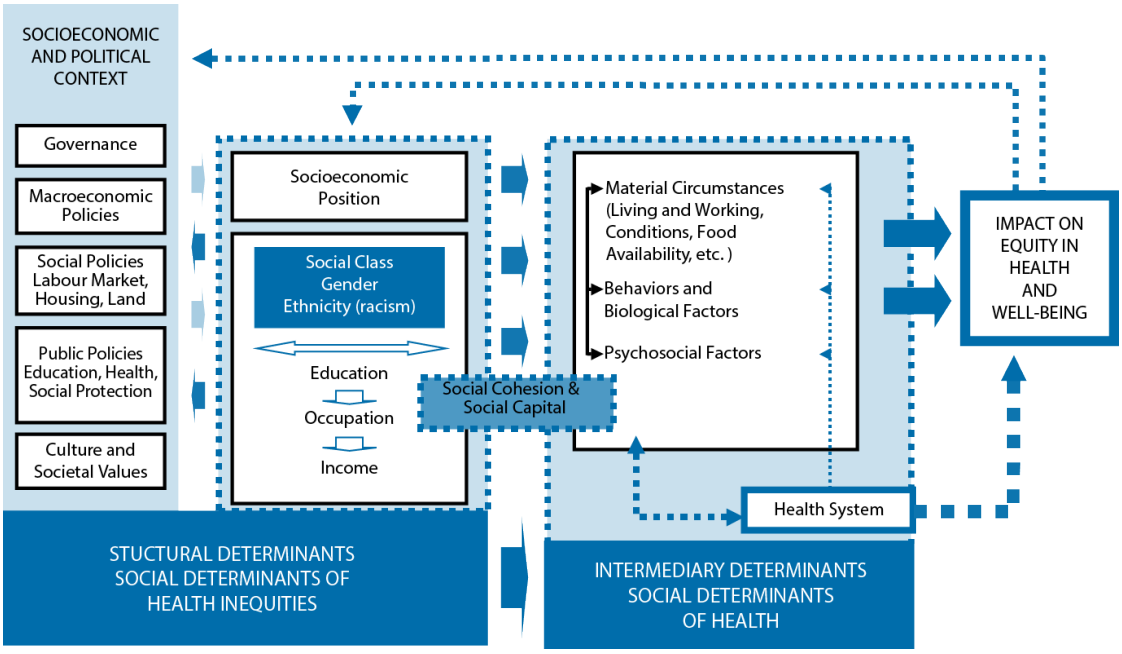

Figure 2 Conceptual framework of the social determinants of health

Similar to the social ecological model, the SDH places the individual within a mosaic of social institutions. Unlike the social ecological model, the SDH provides relationships among all of the components of the social hierarchy through explicit causal pathways. According to this framework, individual health is the product of the structural determinants of the society which produce intermediary determinants that feed back to the structural level in a cycle. The structural determinants are: 1) the socioeconomic and political context, including laws and policies, and cultural and societal values, and 2) the individual's socioeconomic position, which is the product of social class factors including education, occupation and income. This structural context defines the boundaries of the health environment available to member of the society. An individual's health state is further constrained by the additional influence of the intermediary determinants: material circumstances, behaviors and biological factors, psychosocial factors, and the health system as moderated by social cohesion and social capital. Finally, the resultant health states of

the members of the population influence the structural determinants for all of the society.(20) To clarify the operation of this framework consider US seasonal influenza policy.

At the structural level, influenza policy is established by valuing the potential economic and social costs of various policy alternatives, weighed against the potential economic and social benefits of those alternatives. An extreme example might be the comparison between the policies of optional seasonal influenza vaccination vs. compulsory vaccination for everyone in the population. An analysis of these alternatives might find that compulsory vaccination could prevent the most cases of disease, but that the cost of policing universal coverage and the restrictions on individual liberty outweigh the expected health benefits. If, however, the political context was colored by a recent pandemic resulting in mass casualties, the expected benefits might supersede the costs of enforcement and the reduction in civil liberties. In addition to explicit policy directives, the socioeconomic context includes other seemingly unrelated factors. Structural elements such as, urban design, availability of mass transportation, funding for local health departments, school class sizes, and more can all play a role in the epidemiology of seasonal outbreaks. Thus, the decisions made at a societal level can exert additional influences on population health. This effect is translated to individuals though socioeconomic position.

Those with advantageous socioeconomic positions receive greater benefit, or suffer less, from coincidental structural influences. Suppose that a policy of compulsory vaccination for children and optional vaccination for adults were to be adopted. An individual's likelihood of being vaccinated would be a function of their socioeconomic position. An unintended consequence of this policy manifesting in socioeconomic position, might be the allocation of the available vaccine stock to the more profitable insured market resulting in a disruption in supply to the VFC program. This would leave some of the most vulnerable children unprotected. In the adult population, a large

proportion of the more educated and higher earning citizens might opt out of vaccination due to misinformation and pseudo-scientific deception.

Resolving an individual's health state during a pandemic would occur by first solving for the structural effects given the individual's socioeconomic position, then subtracting the effects of the intermediary determinants, adjusting for moderating effects from social capital and then adding effects from the health system. For example, an unvaccinated impoverished child would be likely to fare poorly. In addition to contracting the virus, his/her health might be further compromised by caustic environmental conditions more common in low-income housing, delayed or neglected medical care from overworked or absent parents, and compounded by the endemic levels of psychological stress associated with poverty. Contrariwise, a middle-class vaccine abstainer, might experience less severe outcomes as his/her illness may not be compounded by additional environmental and psychological stressors.

Social capital and the health system provide feedback loops from the intermediary determinants to the structural determinants. Social capital moderates the effects of socioeconomic position, while the health system mediates effects in individual health. For the low-income child, a lack of social capital would offer no counterbalance to the negative socioeconomic effects, while the more affluent adult might be able to further reduce illness intensity by taking advantage of available social supports such as using a family member to help with childcare and cooking for the family.

A final opportunity to adjust health occurs when the individual interfaces with the health system. As a result of these individual's socioeconomic positions, it is likely that the child may never receive medical care or that it may be deferred until the symptoms become so severe that

they become an additional household stressor, while the middle-class adult might access care early enough to benefit from antivirals which prevent additional disruption to daily activities.

At the end of this chain of events, the resulting health states of the impoverished child and the middle-class vaccine objector will feed back to the socioeconomic context for each individual and may establish a new socioeconomic position prior to the next medical crisis. The child who could not be vaccinated suffered a more intense illness as a result of socioeconomic position, the lack of social capital, and minimal mitigation by the health system, this child did not improve in socioeconomic standing and may have even fallen below the starting position. The flu-stricken adult experienced a reduction in the potential severity of the illness resulting from the absence of poverty-related stressors, available social capital, and early access to the health system. While this individual probably did not improve in socioeconomic standing during the illness, the reduced severity, likely prevented a drop in standing if, for example, he/she were to have lost a job due to illness.

The final process in this system occurs when the aggregate experiences of all members of society inform policy, programming and cultural values. If the impoverished child scenario becomes too common or is widely publicized, it may lead to changes in structural level interventions for the disadvantaged. Likewise, the minimized consequences of illness for the vaccine abstainer, might lead others to believe that vaccination is unnecessary. If that erroneous belief were translated into structural inputs (e.g. abolishing compulsory childhood vaccinations) the entire society would suffer as more people contract VPD.

Within the health system, primary care providers are a logical focal point for interventions targeting preventative treatments such as immunization. However, focusing health system interventions too narrowly on the manipulation of individual-level constructs like knowledge,

attitudes, and beliefs about immunization is insufficient to substantially improve vaccination rates. While the common models applied to patient-provider interventions, such as, the health belief model(21), protection motivation theory(22), and the theory of planed behavior(23) can be useful in developing decision aids or in framing educational messages,(24, 25) they are inadequate as a guiding framework to improve population outcomes at either the practice or regional levels because the health system is, itself, a complex system.

1.1.4 Immunization Services as a Complex Adaptive System

Like many other public health initiatives, the US immunization program, functions as a complex adaptive system. A complex adaptive system is a collection of entities that produce an outcome through dynamic, interrelated processes. Complexity occurs when the variability in the relationships among the elements in the system becomes important. Note that being complex is different from being complicated. A system can be complicated without being complex. Complicated systems are characterized by long chains of if-then operations. This logic can even branch out into many alternate pathways, but the final outcome can always be anticipated by a logical flow of predictable intermediate outcomes. A complex system also has predictable processes, but the outcome is dependent on how these processes interact with one another. In a complex system, causal pathways circle back to prior processes to create feedback loops.

For example, vaccine manufacturers want to produce as much vaccine as is necessary to immunize the population without creating a surplus that expires. A complicated version of the system would proceed linearly. Epidemiologists would estimate the required monthly inventory and the manufacturer would produce some fraction of that inventory with every production run. Then clinicians would administer doses. In this system, oversupply or shortage is inevitable since

the supply chain has no awareness of the demand. Adding a feedback loop to the system, makes it adaptable to fluctuations in demand. Such a feedback loop might be a weekly inventory monitoring system where some number of doses is established as a reserve. If the reserve is full, production is halted. If the reserve is not full, production continues. If the reserve is ever emptied, production accelerates, and the reserve number is increased. If doses in the reserve ever expire, the reserve number is decreased. Now the system is taking feedback from one process and turning that into an input for another process, thus making the system adaptable. Because of this ability to modify one process in response to another, the system maintains stability even under inconsistent conditions. (26)

The broader immunization system functions in a similar way, albeit with many more processes occurring at a larger scale. Consider the introduction of the HPV vaccine. Initially, demand for the vaccine and uptake were nil because a vaccine was not available. Once the vaccine was approved for use in the population, demand and uptake rose, however the vaccine was only licensed and recommended for females. Because the primary aim of the program was vaccinee protection from HPV-related cancers, marketing, education, and clinician training centered on the vaccination of pre-teen and teenage girls. When, the Advisory Committee on Immunization Practices (ACIP) recommended the routine immunization of 11 and 12-year-old girls against HPV, CDC added the licensed vaccine to the Vaccines for Children Program (VFC) which guarantees that low income and impoverished children have access to all recommended vaccines. This system *should have* demonstrated increasing levels of coverage among girls and decreasing prevalence of cervical cancers later in life. However, several important relationships in the system created unintended feedback loops that inhibited the rapid adoption that was initially predicted.

First, cost and convenience of the vaccine was a substantial barrier. Not all providers accept VFC and thus some could not access VFC vaccine. Some providers did not stock HPV vaccine. Furthermore, the 3-dose series over six months is recommended at an age when children typically make only annual visits. Second, the selective recommendation fueled a public debate about the perceived risks of the possible sexual disinhibition of vaccinated children and concerns about vaccine safety arose.(27) In a complex adaptive system, stability can be a benefit if the observed outcome is desirable, however in this case, the observed outcome (low rates) was undesirable. Because the feedback loops in the system (high cost, a three-dose series, and perceived risks of vaccination) were stronger than the effects of clinician counseling, widespread uptake was limited.(28) Changing the outcome in a system like this will not happen without modifying the underlying system dynamics. No amount of provider education would prove sufficient to overcome the existing feedback loops.(29)

Fortunately, policy makers, clinicians and scientists recognized the problems and altered the assumptions of the original population models. By including boys and young men in the vaccination effort, women would experience greater protection from HPV-related cancers. Vaccination became "routinized" and large education efforts to prevent cancer occurred in the lay and provider communities. Also, in the face of low rates, the economic benefits of the reduction of other HPV-related disease, like genital warts, head and neck, anal, and penile cancers, further argued for an expansion of the ACIP HPV recommendations.(30) Subsequently the vaccine was licensed for boys and recommended by the ACIP for all adolescents. This expanded the VFC formulary to include males and coverage under the Affordable Care Act occurred. Also, the universal recommendation has likely diminished the strength of the effect of parental refusal. Though risk perception is still cited as a barrier, the shift in public policy may have softened

objections enough that clinicians are now able to overcome parental hesitancy. The result of increased access, enhanced publicity, and routinized provider recommendations is increasing levels of coverage.(31, 32)

This example illustrates that an individual's health is determined by factors well beyond that person's locus of control. While it is tempting to believe that every person can autonomously choose his or her own state of health through rational decision-making, the truth is that all people are subject to unexpected tangential influences that serve to limit the breadth of options available at the individual level.

1.1.5 Implementation Science

Though useful in understanding the context of the immunization system, the theoretical overview presented above offers no practical mechanisms for the alteration of the system dynamics. Only by designing, implementing and evaluating controlled interventions, can the system be coaxed into change. Primary care is an especially useful intervention domain for immunization services. As the health system delegates responsible for coordination of care and preventative treatment, PCPs are ideally positioned to alter system dynamics at the intermediary level. As such, PCPs, their staff, and the patient-provider interaction have been the subject of substantial scientific inquiry. A by-product of this scrutiny has been the observation and description of the factors related to the installation, adoption and maintenance of intervention strategies. The following section discusses the process of integrating evidence-based innovations into clinical practice.

The field of implementation science addresses the process of translating research into practice through change. Change occurs during implementation, or, the institutionalization of the

set of conditions and behaviors required to successfully execute an evidence-based practice. Implementation science is not a replacement for health behavior theory nor a substitute for effective health interventions, rather it is a unifying framework that describes the relationships among factors in the external environment, the characteristics of the organization, the characteristics of the innovation, and the process of deploying the innovation.(33) This systematic study of change reveals solutions and problems outside of the innovation's clinical effectiveness that also contribute to an intervention's success or failure.

Surprisingly, this is a new field of research evolving from the methodical development of evidence-based practices and programs. Though researchers have become better at manipulating health outcomes in small samples of the health system, they have struggled to complete the next logical step which is to consistently replicate and scale these programs in the larger population. Thus, implementation science was born to bridge this chasm between research and practice.(34) As the study of translation progresses, clinicians adopting new innovations will begin to achieve closer results to those predicted in clinical trials.

While implementation science can benefit the deployment of even simple innovations, it is most useful when the innovation targets a complex system with a complex intervention. Immunization is an ideal case for the application of the principles of implementation science. The scope of immunization covers every level of the social ecological hierarchy and has inputs and outputs in all levels of the social determinants of health. Moreover, most single-component interventions will fail to produce a significant change in immunization rates. Achieving measurable improvement requires, multi-component interventions for which the emerging field of implementation science offers guidance to minimize the risk of program rejection and to maximize the effectiveness of a successful system change.

1.1.5.1 Stages of evidence-based program implementation

The successful implementation of a complex evidence-based program is a process that will pass through the four stages pictured in Figure 3 (35): 1) exploration, 2) installation, 3) initial implementation and 4) full implementation. Note that this timeline is lengthy. For ambitious projects, such as a new immunization improvement program (IIP), full implementation may take months or longer to achieve. Also note that the process may continue indefinitely. This is certainly true of immunization. New vaccines will be released, recommendations will change, and staff will turn over. These time-related characteristics should shape expectations of the project. The first step in in an IIP is to come to understand the implementation environment. This happens in the exploration stage.

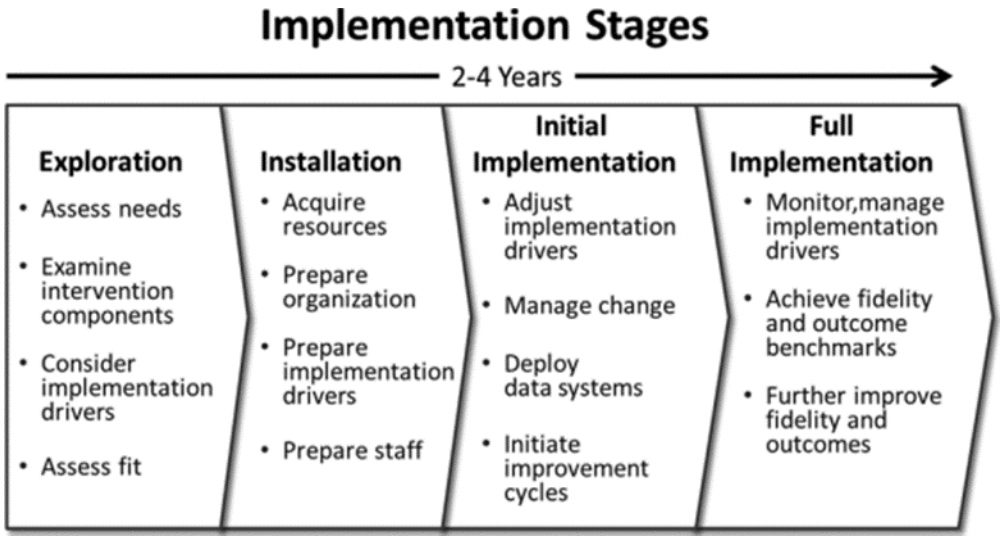

Figure 3 The stages of implementation

Exploration

As the name implies, exploration involves setting aside one's own opinions and seeking to understand the implementation environment from the perspective of other stakeholders. The first task during the exploration stage is to understand what issues contribute to the problem and why they occur (assess needs). The second task is to review available interventions that have

demonstrated improvement to the target outcome in other similar environments (examine intervention components)[1]. And, the third task is to evaluate the capacity of the organization to support the necessary strategies (consider implementation drivers). With that information at hand, one will be able to select the right intervention or components from an assigned intervention (assess fit). I.e. will the proposed strategy solve the identified problems within the constraints of the organizational capacity?

These tasks remain the same for implementations of any size. The methodology used to arrive at an assessment of fit may need to be scaled up or down accordingly. In a small practice, it may be practical to interview members of the staff informally over the course of a few workdays, while in a multi-site healthcare system one may need to collect data through questionnaires, interviews, participant observation sessions, focus groups, or even hire trained personnel to assist with assessment.

Installation

During the installation stage, the implementation team should prepare all of the individuals and resources necessary to perform the intervention. Installation is as much about achieving the social psychological milestone of buy-in, as it is about logistics. Advanced warning helps to smooth acceptance of the changes. If this stage is skipped, the success of the implementation will be jeopardized, or at least delayed, to remediate the oversight and to attempt to hastily acquire

[1] Bertram, et. al (2014) categorize intervention components with further refinement as: (a) model definition; (b) theory bases supporting those elements and activities; (c) the model's theory of change; (d) target population characteristics; and (e) alternative models. Discussion of these intervention components has been omitted in favor of presenting a more accessible approach to implementation of an existing evidence-based immunization intervention.

necessary resources and/or overcome nagging resentments from staff. The ultimate change in outcomes is dependent on the three interrelated and compensatory implementation drivers of competency, organizational systems and culture, and leadership, which will be more fully discussed in the following section.

Initial Implementation

After months, or even years, of planning and development, a new immunization improvement program is ready to be deployed. While it is theoretically possible that all of the preparation will result in a unilaterally adopted and flawlessly executed intervention, the more likely scenario is that the program will encounter unanticipated problems, unexpected obstacles and unpredictable behavior. The primary objectives during the initial implementation stage are resolving these problems, overcoming these obstacles, and managing these behaviors.

Full Implementation

Some interventions may never achieve full implementation while others may become institutionalized rapidly. The speed and degree of adoption is related to the complexity of the change and the fit between the program activities and the skills and resources available to support the implementation drivers. When an organization can meet a program's requirements for staff competency, systems and resources, and leadership dynamics, full implementation will occur with greater fidelity to the prescribed activities then when there is a miss-match between requirements and skills(36). The initial implementation stage is the time to adjust one or both of these parameters until program fidelity can be achieved.

Once the organization is reliably performing the specified activities, focus will shift to maintenance of the new processes and evaluation of outcomes. Full implementation is the time to

evaluate program outcomes at scale. If there is a large discrepancy between the expected and observed outcomes, one can attempt to achieve better program fidelity through the implementation drivers or begin a new exploration phase to choose an intervention with a better fit. Otherwise, the improved outcomes should be monitored for consistency through time.

1.1.5.2 Implementation Drivers

Implementation drivers are the most important determinants of implementation success. The three components of competency, leadership, and organizational environment presented in Figure 4 (35) all contribute equally to an intervention's potential effectiveness. Competency drivers are largely influenced by human resources and staff performance management. Organization drivers reflect the translation of changes in external policies and conditions to internal business practices or treatment protocols. Lastly, leadership drivers, include the availability and characteristics of project leadership.(35) All of these drivers are addressed throughout all of the stages of implementation. In the exploration stage, the implementation team compares what is required by the intervention with what is available within the organization. In the installation stage, the systems and processes that support the program are deployed. During initial implementation, the program is tested, and the implementation drivers are adjusted. Finally, in full implementation, the organization executes the intervention activities with fidelity and continues to build on successes.

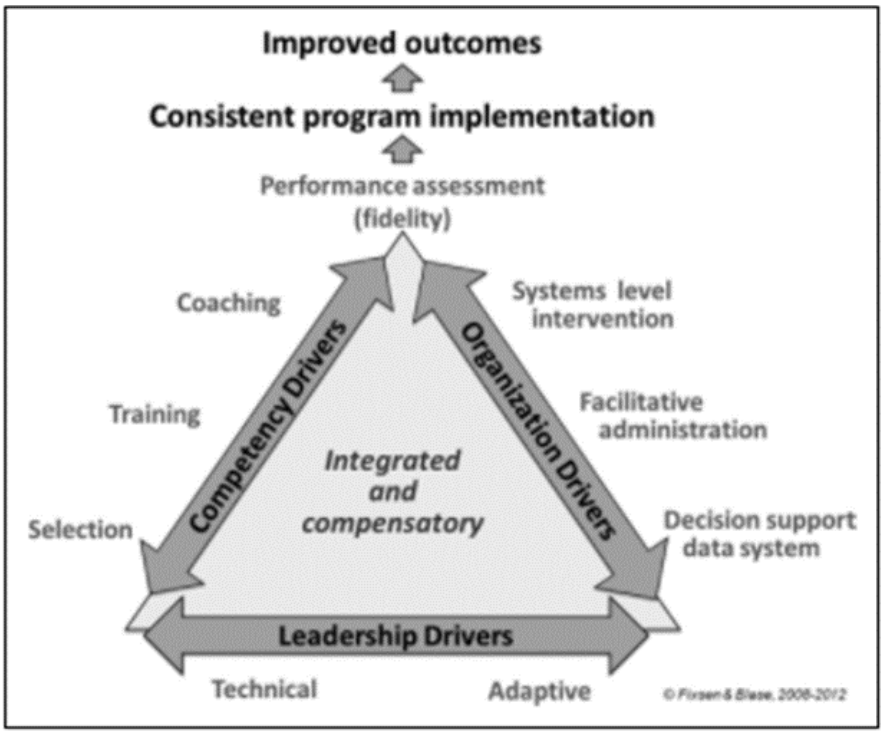

Figure 4 Implementation drivers

The over-arching goal in aligning implementation drivers is to achieve program fidelity.(34) While there is considerable flexibility in how the program is installed and in what components are selected as an appropriate fit for the environment, the actual execution of the prescribed activities should remain as close to those that have demonstrated population-level effectiveness as possible.

A fundamental challenge in any implementation is managing change. Disruption from the process of change can be minimized by using findings from the field of implementation science. Successful implementation of an evidence-based practice will progress through the four stages of exploration, installation, initial implementation, and full implementation. During each stage, competency drivers, leadership drivers and organizational environment drivers are aligned with program requirements and organizational capacity to insure implementation fidelity. Execution of

the program components with fidelity to the evidence-based model will result in a change in practice outcomes.

1.2 Efforts to Overcome the Barriers to Immunization

The Community Preventive Services Task Force (Task Force) is charged with systematically reviewing and synthesizing the results of peer-reviewed intervention studies across a spectrum of population health conditions. The Community Guide, available at http://www.thecommunityguide.org, contains the findings and recommendations reported by the Task Force and includes an extensive section on increasing appropriate immunization. Because the Task Force conducts rigorous evaluations that are peer-reviewed by stakeholders from research, policy, practice, and government agencies, including the CDC, The Community Guide is a trustworthy and comprehensive resource. (37)

In the evaluation of interventions to increase universally recommended vaccinations, The Community Guide presents the findings from 22 recent systematic reviews and recommends 15 of the evaluated strategies. The Task Force suggests that additional research is necessary to issue an opinion on the remaining seven strategies and did not "recommend against" any of the reviewed strategies. (37) The review's logic model groups interventions into the five categories: 1) interventions enhancing access to immunization services, 2) interventions to increase community demand for immunizations, 3) provider-based interventions, 4) interventions to promote seasonal influenza vaccinations among healthcare workers, and 5) interventions to promote seasonal influenza vaccinations among Non-Healthcare workers. (38, 39)

One strength of the Community Guide is its "stock and flow" perspective which assumes that increasing demand for immunization and/or increasing access to immunization will increase the number of patients seeking vaccination. When those patients engage with the health care system, provider-based interventions will increase the proportion of vaccinated individuals. This framework is logical from a population-based disease transmission perspective as it mirrors the common susceptible, infected, recovered (SIR) model that is very familiar to epidemiologists.(40)

Another strength is that front-line immunization champions, would likely find the common themes in the recommendations of the Community Guide intuitive. First, simply increasing access to immunization is effective in multiple settings and across diverse populations. Reducing financial burdens, reducing opportunity costs, and offering more convenient locations for vaccination all contribute to increased uptake. Second, many people seem willing to be vaccinated when they are reminded, it is routine or required, or influential social factors are leveraged to encourage vaccination intention. Also, knowledge of vaccine status and vaccine education are necessary but insufficient to elicit vaccination intention. Third, practitioner-based interventions are sensitive to increased system efficiency and automation and achieve maximal effectiveness when implemented in combination with other strategies. Finally, clinicians respond to motivation.

Limitations exist; a review of Vaccination illustrates that this framework has limited use from a patient-panel, clinician-centered perspective, since the organizational scheme used in the Community Guide blends the intention of the intervention (Enhancing access and increasing demand) with the locus of intervention (provider, system, or workplace). Additionally, many of the strategies involve socioecological levels outside of a clinician's sphere of influence. Thus, practitioners who want to overcome barriers to immunization need a more action-oriented framework to conceptualize possible intervention strategies. Also, most provider-based

interventions target a single or small set of PCP-centered inputs. Consequently, the observed effects are minimal when the PCP is isolated from other components in the immunization system. Though implementing interventions in combination is recommended, when multiple strategies are incorporated into a single intervention, PCPs can quickly become overwhelmed with implementation complexity. Therefore, a successful PCP-centered immunization intervention requires the thoughtful combination of evidence-based strategies into a multi-faceted program that respects the limitations of the primary care team and incorporates the best-practices of implementation science.

Table 1 Task Force Recommendations and Findings to Increase Appropriate Vaccination

	Recommended	Insufficient Evidence	Recommend Against
Enhancing Access to Vaccination Services			
Home Visits to Increase Vaccination Rates	X		
Reducing Client Out-of-Pocket Costs	X		
Vaccination Programs in Schools and Organized Child Care Centers	X		
Vaccination Programs in WIC Settings	X		
Increasing Community Demand for Vaccinations			
Client or Family Incentive Rewards	X		
Client Reminder and Recall Systems	X		
Community-Based Interventions Implemented in Combination	X		
Vaccination Requirements for Child Care, School and College Attendance	X		
Client-Held Paper Immunization Records		X	
Clinic-Based Education when Used Alone		X	
Community-Wide Education when Used Alone		X	
Monetary Sanction Policies		X	

Table 1 Continued

Provider or System-Based Interventions			
Health Care System-Based Interventions Implemented in Combination	X		
Immunization Information Systems	X		
Provider Assessment and Feedback	X		
Provider Reminders	X		
Standing Orders	X		
Provider Education when Used Alone		X	
Interventions to Promote Seasonal Influenza Vaccinations among Healthcare Workers			
Interventions with On-Site, Free, Actively Promoted Vaccinations	X		
Interventions with Actively Promoted, Off-Site Vaccinations		X	
Interventions to Promote Seasonal Influenza Vaccinations among Non-Healthcare Workers			
Interventions with On-Site, Reduced Cost, Actively Promoted Vaccinations	X		
Interventions with Actively Promoted, Off-Site Vaccinations		X	

2.0 The 4 Pillars™ Practice Transformation Program

Zimmerman and Nowalk (41) offer the 4 Pillars™ Practice Transformation Program for Immunization as a multi-component immunization improvement intervention targeting primary care providers. The program aggregates existing evidence-based strategies applicable to PCPs into the context of the clinical environment by defining a taxonomy of critical leverage points. These are presented as the 4 Pillars™, which are: 1.) convenience and access, 2.) patient communication, 3.) enhanced vaccination systems, and 4.) motivation. Additionally, the process of implementation is supported with protocols and custom-created software designed to mitigate many of the threats to behavioral interventions by increasing fidelity. This hybrid approach, where the implementation of the intervention is supported as strongly as the intervention strategies themselves, has led to encouraging successes in health outcomes. (41-43) Clinical trials of the 4PPTP have shown increased uptake of seasonal influenza vaccine in children, (44-47) and seasonal influenza, pneumococcal, and pertussis vaccines in adults. (42, 48) Also, evaluation of the clinical implementation, supports the Community Guide recommendations for multi-faceted health care system-based interventions. (37, 49)

2.1 Pillar 1: Convenience & Access

Access to care is a strikingly complex barrier to immunization. Truly providing complete access to all patients is elusive and can be frustrating as barriers are removed only to reveal new hidden obstacles.(50) Similarly, some practitioners may overlook opportunities to increase access

to immunization by focusing on the societal level impediments rather than the myriad small ways they can make vaccines more widely available to their patients.

Penchansky and Thomas (51) suggest that access to care has five dimensions that describe a patient's "degree of fit" with the health system. Primary care providers can extend this taxonomy to describe a given patient's degree of fit with their practice, their vaccination services, and even a specific vaccine.

Availability is the value of the relationship between supply and demand. A primary care provider is available when a community has enough clinicians to offer services to the population. Influenza vaccine is available when a provider has enough stock to immunize all the patients who are eligible to receive it during the flu season.

Accessibility is a measure of the perceived distance between the location of the patient and service. A clinic is accessible if it is within a reasonable commute from a patient given the available transportation. A vaccine is accessible if it is administered at the patient's home or workplace.

Accommodation describes the patient's perception of feasibility to receive care. A schoolteacher may perceive a clinic as accommodating if s/he can schedule an appointment after school hours or on the weekend. A provider who offers no-wait, walk-in flu shots is showing accommodation for flu vaccination.

Affordability measures the patient's ability to pay for the services provided as well as their perceived value of the services and knowledge of payment options. A primary care provider is affordable if the patient can pay for routine and unexpected care without extraordinary financial burden. A vaccine administration is affordable if a patient is willing to sacrifice the time, money, and effort necessary to receive the vaccine as well as any research and paperwork necessary to receive reimbursement for out of pocket costs.

A*cceptability* relates an individual's knowledge, attitudes, and beliefs about a resource to the actual characteristics of that resource. A PCP is more likely to be acceptable to a patient if the patient perceives the clinician as willing to listen. A vaccine is more likely to be acceptable to a patient if the clinician presents the benefits, common side effects and the uncommon risks.

The preceding examples of access to primary care and access to immunization are only a start to the methods a practitioner might employ to increase access to vaccination services. 2.1.1 lists evidence-based strategies from the 4PPTP that can be used to increase the convenience to and access of vaccination services.

Offering accessible vaccination services is key to reducing social and healthcare inequities. (52) Providing equal access means solving problems that are subtler than a simple determination of insurance coverage. While expanding the population of insured individuals may be out of the scope of an individual physician, that physician can certainly manipulate many elements of availability, accessibility, accommodation, affordability, or acceptability to increase access to vaccination services.

2.1.1 Pillar 1 - Convenience & Access Strategies

- Use every patient visit type as an opportunity to vaccinate, including nursing, acute, chronic care, follow-up visits for visits for another vaccination.
- Offer open access/walk-in vaccination during office hours.
- Promote simultaneous vaccination (e.g., offer other vaccines at the time of influenza vaccination.)

- Hold express vaccination clinics outside normal office hours where only vaccines are offered, with streamlined flow systems for check-in, screening, and record keeping.
- Create a dedicated vaccination station.
- Extend the influenza vaccination season by vaccinating as soon as supplies arrive and continuing to vaccinate as long as flu is circulating in the community.

2.2 Pillar 2: Patient Communication

Patient refusal is one of the most obvious barriers to vaccination and is undoubtedly the most frequently blamed "reason" for sub-optimal vaccination rates. Refusal is a problem but occurs much less frequently than one might imagine. Leask and Kinnersley (53) estimate that less than 2% of parents in a sample of western countries are absolute refusers with the remaining 98% ranging from late or selective to unquestioning acceptor. While one should consider how to communicate with vaccine refusers, one should also refrain from allowing the vocal minority to become overly distracting. In actuality, the most important instances of patient communication occur well before the point of asking for consent to vaccinate.

The 'Communicate to vaccinate' project developed a taxonomy of communication objectives identified in published immunization interventions.(54) The range of potential audiences and communication strategies resulting from the project underscores the importance of examining every patient engagement for opportunities to optimize communication. Though all of the communication purposes presented in Figure 5 (54) are potentially useful, primary care providers will likely use the objectives related to reminder and recall and patient education the

most frequently. Of those two aims, reminder and recall interventions are more effective in increasing uptake if no other strategies are enlisted while patient education requires the support of additional leverage points to achieve a noticeable increase in vaccine uptake.(37, 38)

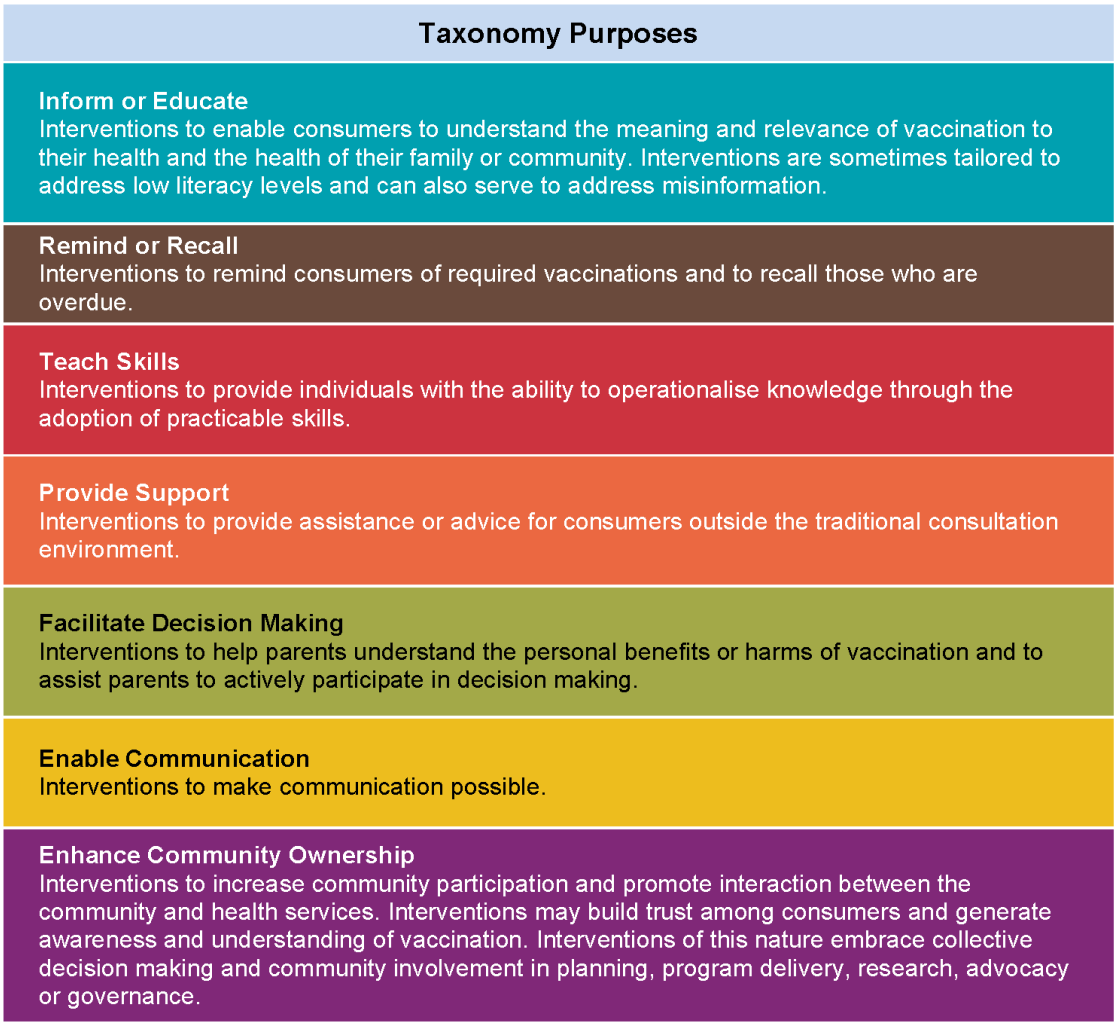

Figure 5 COMMVAC taxonomy purposes and definitions

To many practitioners, patient education can become the default intervention strategy for every quality improvement program. This makes sense as clinicians are passionate about patients as individuals and want to achieve the most healthful outcome for every patient at every visit. While this is important, effective patient communication efforts must include strategies that act well outside of the exam room. Ideally, effective patient communication eliminates the need for

intensive education because the patient walks into a visit asking for a vaccine. Additionally, focusing communication efforts on short, routine interactions can reach the largest number of patients with the least amount of effort.

Consider the time prior to a patient's appointment in the context of the Transtheoretical Model(55) as illustrated in Figure 6. Prior to any external cues, all of the eligible and unvaccinated patients will exist in the Precontemplation stage. Some proportion of these people may spontaneously schedule appointments for vaccination in response to school or workplace requirements and some others in response to media or other mass communication initiatives. The remainder (especially adults) will need to be shepherded onto the schedule with a *Remind or Recall* program. This initial contact is a moment to create awareness of vaccination and to move patients from a Precontemplation stage into a Contemplation stage. Every subsequent encounter prior to the visit offers another opportunity to *Inform or Educate* patients with positive messages or reminders about vaccination. Once in the office, posters, fliers, and decision aids can help patients work through the Preparation stage or bring any precontemplators who ignored prior cues into the process. Rooming the patient and taking vital signs are opportune times to *Enable Communication* and to *Facilitate Decision Making* by checking vaccination status and exposing patients to more posters, fliers, and decision aids. If the practice has implemented standing order protocols for vaccination (see Pillar 3) all vaccines could be administered by the rooming medical assistant or nurse prior to the first contact with the clinician. Finally, during the clinician's consultation, any remaining objections to vaccination can be addressed. By the end of the communication cycle, all patients will have been given every possible opportunity to overcome any personal reluctance to immunization and to act by accepting all overdue vaccines.

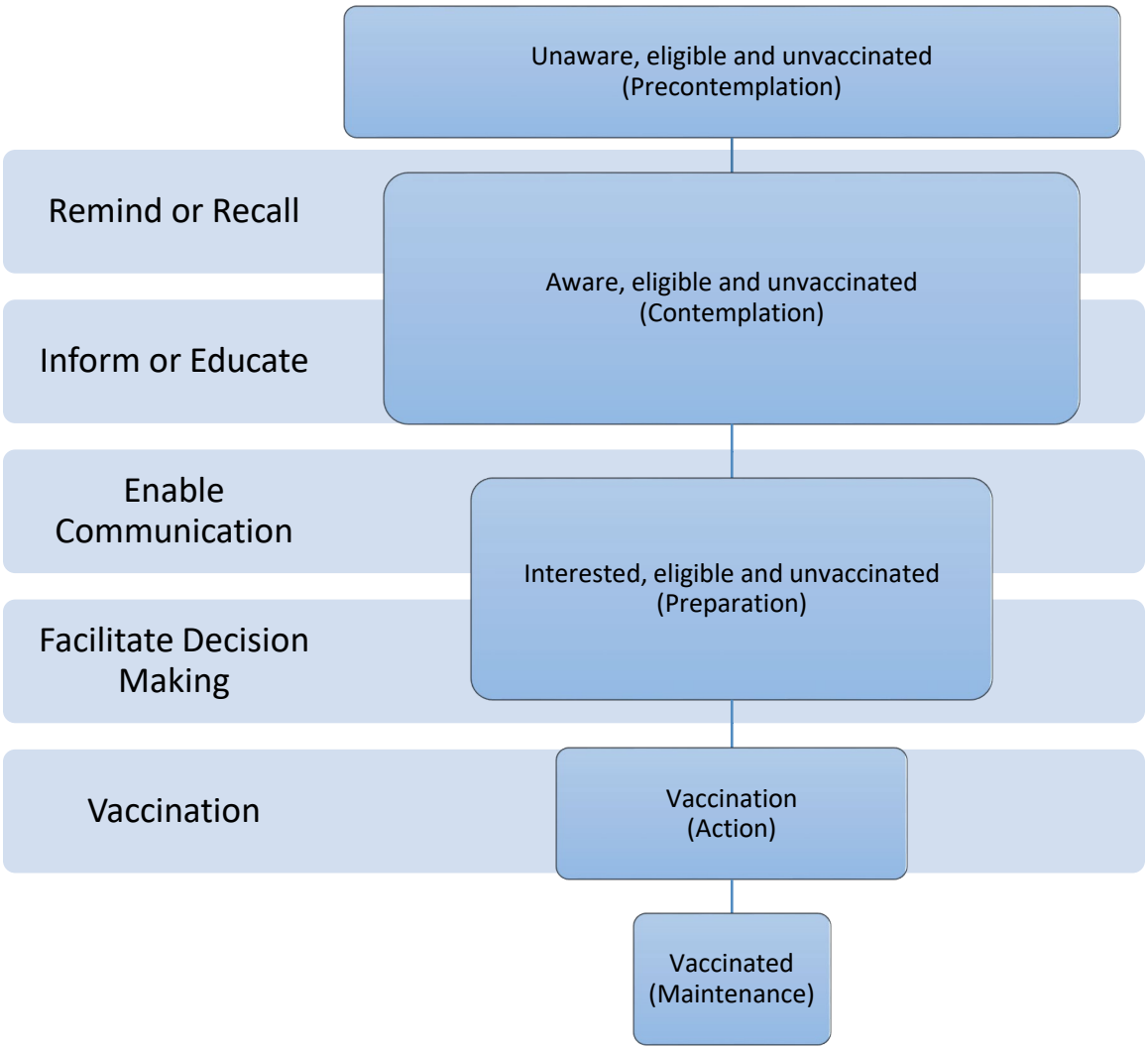

Figure 6 Patient communication opportunities prior to, and during appointment

Communication with patients about immunization, however, is much more than carefully delivered monologues in the exam room. While skillfully responding to the concerns of vaccine hesitant patients is important, a much larger audience exists outside of the office walls. Using every engagement with patients as an opportunity to enable communication and to provide a small dose of education or information will deliver a sustained and consistent message that cannot be

duplicated in a single appointment. See 2.2.1 for a list of evidence-based patient communication strategies from the 4 Pillars™ Practice Transformation Program.

2.2.1 Pillar 2 - Patient Communication Strategies

- Enroll patients in electronic health portal.
- Provide information about vaccine preventable diseases at the beginning of every visit.
- Train staff to discuss vaccines during routine processes such as vital signs.
- Discuss the serious nature of vaccine preventable diseases.
- Promote 100% vaccination rates among staff to set a good example.
- Use on-hold messages, poster, fliers, electronic message board, website posting, and social media to promote vaccination.
- Reach out by email, phone, text, mail, health portal etc. to recommend vaccines that are due and about arrival of influenza vaccine supplies.

2.3 Pillar 3: Enhanced Vaccination Systems

For decades, epidemiologists, clinicians, policymakers, and manufacturers have continued to extend an increasingly robust immunization infrastructure closer and closer to each member of the population. As always, the familiar dyad of the physician and patient are left at the end of that complex chain to overcome any barriers. As a public health program, immunization is both blessed and cursed by a dependence on standardization and automation. Immunizing the entire human race

can only be achieved through standardization, routinization, and complex systems support. This is a benefit to the program of immunization because ambiguity in any part of the process is systematically replaced with well documented policies and procedures. This prescriptive information can then be transformed into algorithms, programs, and industrial processes that eliminate a great deal of human intervention. Unfortunately, this dependence on automation and standardization can introduce new problems. Errors can impact enormous numbers of people and conversely, improvements can take substantial time to deploy.

There are three major systems that have demonstrated positive influences on vaccination outcomes: 1) immunization information systems, 2) provider reminders, and 3) standing orders for vaccination. Additionally, clinicians should also consider how their unique office systems can be enhanced to support vaccination services.

2.3.1 Immunization information systems

An immunization information system (IIS) is a centralized repository of personally identifiable vaccination information for individual members of the served population. Nearly all US states now operate an active IIS however the features and functionality of each system is variable. During this period of transition to centralized vaccination registries, the Immunization Information Systems Support Branch, CDC - National Center for Immunization and Respiratory Diseases (NCIRD), directs expectations through an incrementally more complex set of functional standards for IIS. These standards were introduced in 2001, incremented in 2013 and will be evaluated again in 2017.(56) The technical standards support the programmatic goals of CDC-funded Immunization programs and state vaccine registries listed in 2.3.2 .

2.3.2 **Programmatic goals of CDC-funded Immunization programs** (56)

- Support the delivery of clinical immunization services at the point of immunization administration, regardless of setting.
- Support the activities and requirements for publicly purchased vaccine, including the Vaccines for Children (VFC) and state purchase programs.
- Maintain data quality (accurate, complete, timely data) on all immunization and demographic information in the IIS.
- Preserve the integrity, security, availability and privacy of all personally identifiable health and demographic data in the IIS.
- Provide immunization information to all authorized stakeholders.
- Promote vaccine safety in public and private provider settings

In practice, this registry system will overcome the frustrating and all too common barrier of accurate assessment of vaccination status. When fully implemented, an IIS will programmatically record detailed information for all vaccine administrations and report relevant data to authorized requestors on demand. This simple concept will enable automated information sharing among vaccine service providers, public health services, consumers, and possibly other participants in the national immunization program.(57) Despite the obvious benefits to be gained from a fully implemented IIS and conceptual simplicity, national deployment has been slow. Offering access to sensitive health information to such a breadth of stakeholders has a monumental list of challenges and threats and has necessitated a strategy of slow and deliberate incremental advancement.

Unlike some other system enhancements, clinicians will likely have minimal involvement in the continued institutionalization of IIS but will reap ever increasing rewards from background

improvements to the infrastructure. The most important action item for providers is cooperation with any manual processes required to interface with the system, especially when accuracy can be compromised. Manually entering vaccination data into multiple databases, for example, may seem burdensome, but activities like this help every other stakeholder in the system to offer better services to patients. Ultimately, these chores will be replaced by the robust automation of the transfer of data between the EMR and the IIS. See 2.3.5 for some common strategies to maximally leverage IIS.

2.3.3 Provider Reminder Systems

Provider reminder systems notify clinicians that a vaccine should be administered to a specific patient at the point of care. The mechanism of this notification is less important than its existence and can take whatever form fits within the patient workflow. This strategy is effective for any vaccine and for any age patient and in nearly all clinical settings.(37) Reminders can be informally implemented as a note on a chart or formally implemented as programmatic notifications in the EMR (a.k.a., best practice alerts). (58, 59) The most important considerations are that the provider responsible for vaccination takes notice of the reminder during the patient encounter, and that the reminder is accurate.

The mechanism of action for provider notifications has not been well studied.(60) However, there are numerous reports in the medical informatics literature of implementation details in EMR systems that may have an impact on outcomes. Additionally, there are some unintended consequences of the success of clinical decision supports like provider reminder systems. “Alert fatigue,” and cognitive overload are familiar concepts to most clinicians who work with an EMR.(61) The following elements are key elements of provider reminders:

What is displayed in the content of the reminder.

How the reminder is presented to the clinician. This may include the use of consistent colors, visual cues, and terminology as well as the required level of interruption to the patient care workflow

Where the reminder is presented in the salience hierarchy. For example, as a dialog box alert that appears immediately upon opening a patient record or as a footnote that is visible only after navigating deeply into the record.

When the reminder is presented in the patient care workflow. (62)

Because of the variability in office systems, primary care practices will need to implement provider reminders in whatever form makes the most sense within the business, operational structure and patient care workflow. Some organizations will be able to simply turn on functionality provided by an EMR vendor, some will need to define and enable custom prompts, while others will need to rely on the creativity of staff to create manual prompts outside of the EMR. Every implementation will have unique shortcomings, but reminders of nearly any description are better than missing an opportunity to vaccinate.

2.3.4 Standing Orders for Vaccination

Standing orders protocols for vaccination (SOP) allow authorized health care staff to assess vaccination status and administer vaccines without an examination or specific order from a physician at the time of the administration. Standing orders are established by clearly defining a protocol for vaccine status assessment and vaccine administration. The SOP can range from broad, including many vaccines and many patent sets, or narrow including a single vaccine and a single

patient set. This protocol is then approved by the appropriate personnel responsible for patient care and disseminated through training to all relevant clinical staff.

Standing orders for vaccination can be one of the more difficult to implement provider-based immunization interventions. However, the rewards in efficiency, increased vaccinations, and prevented cases of disease are well worth the effort, especially in the adult population.(63, 64) Both the Task Force on Community Preventive Services (65) and the ACIP recommend the use of SOPs in many contexts.(66) In fact, the positive impact of SOPs can hardly be understated. Among a sample of elderly inpatient hospital stays, the use of SOPs increased the identification of pneumococcal vaccination opportunities from 8.6% to 59.1%.(67) In a randomized trial of 3777 hospitalized patients comparing SOPs to physician reminders, SOPs resulted in a 42% influenza vaccination rate vs. 30% from provider reminders, and a 51% pneumococcal vaccination rate vs. 31% from provider reminders.(68) In a university-based practice, a retrospective analysis of patient visits over four years showed that the physicians who used SOPs achieved an influenza vaccination rate of nearly double those who did not use SOPs (63% vs. 38%).(69) Similarly, an implementation in an urban family medicine center resulted in a 1.4 fold increase in influenza vaccinations.(70) Clearly, all primary care clinicians should strongly consider adopting standing orders for vaccination.

Standing orders are regulated by state law.(71) Since standing orders can be used in many healthcare settings such as hospitals, clinics, medical offices, and long-term care facilities, and can cover many provider roles such as, nurses, pharmacists, and medical assistants, describing specific regulatory details is difficult. Despite the inherent regulatory complexity, standing orders are a

well-known health care process with clear guidelines and prolific documentation.(66) Therefore, development and implementation of SOPs need not be stymied by excessive legal caution.[2]

Unquestionably, implementing standing orders can be a challenge in some environments, but the healthcare benefits far outweigh the organizational effort. There are many excellent resources available from the CDC and other reputable partner organizations to help healthcare organizations and primary care providers plan and establish SOPs. A particularly useful library is maintained by the Immunization Action Coalition (IAC) at http://www.immunize.org/standing-orders.

Primary care providers must assess the office environment holistically to maximize the effectiveness of immunization systems, provider reminder systems, and standing orders for vaccination. See 2.3.5 for some common ways to enhance primary care office systems for immunization. These deep level alterations in routines, habits, and procedures will ultimately take less effort and result in much larger effects than from any campaign-oriented initiative.

2.3.5 Pillar 3 - Enhanced Vaccination System Strategies

- Ensure sufficient vaccine inventory to handle increased immunizations.
- Assess vaccination eligibility for every patient encounter by a systematic mechanism: (1) review of EMR prompts, (2) vaccination as a vital sign, and/or (3) create huddle report at beginning of session of unvaccinated patients.

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[22] The George Washington University Center for Health Services Research and Policy, School of Public Health and Health Services provides a wealth of information regarding the governance of immunizations. Interested readers can access materials at http://publichealth.gwu.edu/departments/healthpolicy/immunization/

- Review accurate EMR vaccination record keeping.
- Update EMR with vaccinations as they are administered.
- Update EMR with vaccinations given elsewhere.
- Assess immunizations as part of vital signs.
- Establish standing order protocols for nursing and other patient care staff to vaccinate without an individual physician order.
- Develop systematic process for vaccinating every person with a vaccination need, such as standing orders or pending/queuing an order in the electronic health record.

2.4 Pillar 4: Motivation

The fourth pillar of the 4PPTP is Motivation of the clinical team. Making changes to established workflows and to office systems is not easy. A common objection to any quality improvement program is some variation on the lack of time and resources. From this perspective of resource scarcity, the very thought of conducting a deep, multi-system, multi-component intervention is almost farcical. Yet if change in outcomes is expected, then some change must occur. Faced with this reality many clinicians fall to the default intervention; education. The assumption is natural. One assumes that if he or she knows more, or can teach patients more, then positive results will follow. Unfortunately, in the domain of immunization, education is necessary, but not sufficient, to achieve measurable changes in vaccination rates. The kinds of changes that are required stress leverage points at every level of the healthcare organization and beyond. Immunization interventions are complex, multi-faceted, and involve many stakeholders. All seasoned clinicians will likely admit to having participated in at least one spectacular failure of a

complex intervention during his/her career; one that never got off the ground or if it did take flight, crashed into a wall of obstinate habits, stoic willfulness, or entrenched bureaucracy. Motivation is the dynamic that pushes individuals to move past these barriers.

An observant reader may have already noted that the majority of strategies to overcome immunization barriers are really designed, though automation and habituation, to overcome our shortcomings as human beings. It is laughably ironic that engineering around human fallibility is, itself, subject to yet another level of human interference. Even the most carefully orchestrated and flawlessly planned quality improvement program can be hamstrung at the human/plan interface. But there is more to this story than fatalistic pessimism. How does one achieve change if it is so hard to do? How is it that some of the most haphazard and impromptu programs can succeed? Why do some practices consistently immunize the majority of their patients under the same organizational constraints? The answer, of course, is motivation. (72, 73)

The Community Guide recommends assessing vaccine providers' performance and offering feedback.(37) Though there is considerable evidence that feedback on past vaccination performance tends to increase future performance, the active mechanisms are relatively unexplored. The exact nature of an "audit" and of "feedback" is highly variable. For example, in the literature reviewed by the Community Preventive Task Force, an audit may be conducted as infrequently as every five years or as often as weekly. Similarly, feedback may be a list of unvaccinated patients, provider education, or even financial incentives tied to vaccination rates. Also, few studies examine audit and feedback in isolation. Many reports include co-occurring interventions or are confounded by secular trends. More research will be necessary to isolate and test different methodologies and causal pathways.(74)

Organizational motivation is a potential mediator in the effectiveness of audit and feedback strategies. Immunization interventions are complex and often involve individuals and business units who do not have close working relationships. Special care should be taken to engage all stakeholders in appropriate planning and preparation to secure institutional buy-in of the program. Failure to do so, may result in insufficient institutional motivation or even overt sabotage that will derail the project. (75) Applying the principles of implementation science can help to guard against these risks. The planning, deployment, and implementation of the program should be considered as carefully as each of the program activities.

Immunization programs are dependent on team participation. If clinicians improve individual performance with audits and feedback, it stands to reason that teams will improve group performance with the same. The 4PPTP recommends the nomination of an immunization champion (IC) to serve as a team motivator.(48) This individual should be respected by the staff as a leader and be able to guide staff through system changes. (49) The IC should also have strong interpersonal skills and enjoy frequent communication. The ideal IC finds win-win solutions to conflicts and demonstrates tenacity in overcoming roadblocks. Finally, the IC should be committed to the quality improvement goal and be nominated as the IC through purposeful consideration and not simply by default.

Section 2.4.1 lists evidence-based strategies that the IC can employ to provide feedback to the team. In generating motivation, the quality of the audit is less important than the quality of the feedback. Obviously, audit results must be truthful, but absolute precision is unnecessary. ICs should use the data at hand to develop the best possible description of the practice's baseline vaccination rates, generate reasonable but challenging targets and then start implementing strategies to try to improve rates. Someday all practices using an EMR will be able to summon an

accurate population-based report of real-time vaccination rates. Until that day arrives, using the readily available reports and measuring success as a change over baseline is sufficient. If no reports are available, simply tracking the number of doses administered per period, or manually auditing some small sample of charts is preferable to implementing a quality improvement program with no measures of effectiveness.

Practice managers and organizational leadership can also provide a special kind of motivation. Operational policies like standing orders can be used to describe required job performance standards. By extension, employees can be compelled to fulfill these standards as a condition of employment. Though tempting, the formalization of best practices into job requirements may lead to more employee dissatisfaction than productivity.(76)

2.4.1 Pillar 4 - Motivation Strategies

- Create a chart to track progress. Set an improvement goal and regularly track progress (e.g., daily or weekly). Post the graph of progress in a prominent location and update it regularly.
- Provide ongoing feedback to staff on vaccination progress at staff meetings or through other forms of communication.
- Create a competitive challenge for the most vaccinations given among staff.
- Provide rewards for successful results to create a fun-spirited environment.

2.5 The Evolution of the 4 Pillars™ Practice Transformation Program from Clinical Trials to Public Health Intervention

The 4PPTP has been clinically tested across a multitude of experimental conditions. Results of these trials of the 4PPTP have shown increased uptake of seasonal influenza vaccine in children; (44-47) meningococcal and Tdap vaccines and HPV initiation and completion in adolescents; (77, 78) seasonal influenza, pneumococcal, and pertussis vaccines in adults; (42, 48, 79) and pneumococcal vaccines in older adults. (80) Moreover, each application of the program offered opportunities to improve the delivery of the intervention methods culminating in the systematic and scalable current version of the program.

The earliest version of the program was developed from an intervention to increase adult immunization rates among minority patients of inner-city health centers.(81) Investigators used a before-after design with four clinics and maintained a fifth site as a concurrent control. During the intervention period for each site, clinical staff were provided education on immunization in primary care and potential strategies for improvement sourced from systematic literature reviews. Each site selected strategies from a menu of options according to the staff's perceived expectation of feasibility and effectiveness in their setting. Some examples of selected strategies were:

- Adoption of standing orders for vaccination
- Hanging of reminder posters
- Looping video in waiting room
- Mailed reminders for immunization including a coupon for a free vaccine
- Walk-in influenza clinic
- Recognition for prolific vaccinator

Among a random sample of patients aged 50 years old or older (n=568), the influenza vaccination rate increased from 27.1% to 48.9% (P<.001) and the PPV rate increased from 48.3% to 81.3% by the conclusion of the program in intervention sites. In the control site, changes in these rates were minimal and statistically insignificant. Logistic regression analyses controlling for age, race and sex, showed that rates for older adults (>65 years old) improved the most and that non-white individuals benefitted as much as white individuals. These findings suggested that the intervention was successful in the population and especially effective in the most vulnerable and underserved sub-populations.

Having demonstrated success in older adults, Zimmerman et al. improved the program and tested its effectiveness to increase childhood influenza vaccination rates of primary care providers serving disadvantaged populations. (46) In this cluster randomized trial, twenty primary care practices were stratified by practice and patient characteristics and then randomized to intervention or control arms. Practices in the intervention arm received the intervention prior to the 2010-2011 flu season. Practices in the control arm were informed that their intervention would begin in the following season.

Preparation for this trial solidified the conceptual framework of the program. Insight gained during the previous effort led to two important changes in the program. First, the evidence-based strategies were organized into "The 4 Pillars" which emerged as: Pillar 1 – Convenient vaccination services; Pillar 2 - Notification of patients about the importance of immunization and the availability of vaccines; Pillar 3 - Enhanced office systems to facilitate immunization; Pillar 4 - Motivation through an office immunization champion. Second, the delivery of the intervention was orchestrated using Diffusion of Innovations theory. (82) These enhancements evolved from

careful observation of the behavior of clinicians and staff during program adoption and the need for standardized and repeatable intervention delivery methods.

During the initial trial, investigators observed that the intervention protocol appeared to have been enhanced by spontaneously emerging system dynamics. In the published discussion of the results, the investigators propose that the collaborative engagement of the clinical teams may have contributed to the emergence of an unexpected catalyst contributing to the improvement of immunization rates. Though this tactic was employed to elicit multicultural perspectives in strategy selection, it appears to have also stimulated enhanced engagement and/or adoption of the program. Even a decade later, this self-actualizing methodology remains novel among the more focused and prescriptive models of quality improvement centered on clinician education. Similarly, in reviewing the proposed evidence-based strategies, clinicians recognized that their practices would have to alter more than just the clinical encounter to maximize opportunities to vaccinate their entire patient panel. Thus, the scope of strategies selected by the sites included a much broader context than the single interaction with an unimmunized patient. Rather, clinicians chose to focus change on structural and organizational leverage points that engage the entire treatment team as well as the unvaccinated in cooperative solutions beyond simple patient education.

The awareness of these environmental contributors to program effectiveness required a new layer of complexity in the intervention. The 4 Pillars™ schema was developed to represent a taxonomy of strategies organized around influential processes in a larger perspective of preventive care. Each pillar captures a necessary-but-insufficient spectrum of processes that are associated with improved vaccination uptake. During implementation, clinicians were instructed to select strategies from each of the pillar domains so that the program remained manageable while still including all of the components necessary to produce measurable long-term results.

Likewise, the adoption of a theory-informed deployment strategy became necessary to strategically harness the amplifying effects of inter-clinician relationships. Diffusion of Innovations theory was a natural fit for this aim as it focuses on moving a large population toward behavior change through the early adoption of the desired behavior by a relatively small number of individuals. With reinforcement, more individuals adopt the behavior until a tipping point shifts environmental dynamics and the new norms become a more desirable state that further accelerating adoption.

As predicted, the intervention significantly elevated influenza vaccination rates in the pediatric population. Among patients aged 9-18 years, overall improvement was 9.9 percentage points in the intervention group vs 4.2 percentage points in the control group. Additionally, when controlling for patient and practice characteristics, likelihood of vaccination increased for non-white children in all age groups.(47) However, a more interesting finding appeared in a subsequent analysis of post-intervention maintenance. One year after completing the program, the intervention group maintained the gains achieved during the program and increased an additional 0.4 percentage points ($P > 0.05$) without any further contact from the study team.(44) This finding suggested that the intervention achieved a change in the system which persisted beyond the termination of the program.

Seeking to expand the reach, consistency and sustainability of the intervention, the research team initiated a larger multi-center trial. This cluster randomized trial was conducted in primary care practices in the Pittsburgh and Houston regions and targeted the improvement of specific vaccination rates in adolescents and adults. The expanded scope of required content, geographic distance and increased number of participant clinicians necessitated further enhancements to the

intervention protocol. With these enhancements, the program achieved significant reductions in missed opportunities to vaccinate adults leading to an improved vaccination rate. (83)

The cost effectiveness and potential public health impact of the program have also been calculated from the research data and reported for select scenarios in the US adult population. These evaluations, discussed below, report that the program is cost-effective and would likely deliver value at the population-level. (84, 85)

The 4PPTP is more than a theoretical framework for immunization improvement. The concepts discussed above have been integrated into a systematic and scalable intervention designed to be deployed with fidelity across a variety of primary care practices, organizations, and patient populations. This intervention methodology was concurrently developed with each increasingly complex clinical trial of the 4PPTP constructs. The most recent evaluations of the program, which will be discussed in subsequent chapters, measure effectiveness in real-world applications with teams who have adopted the program as a clinical care quality improvement effort rather than as participants in controlled laboratory conditions.

2.6 Knowledge Gaps

The 4 Pillars™ Practice Transformation Program for Immunization is a promising step forward for immunization interventions executed in primary care. Fidelity with evidence-based strategies is optimized, even in a complex multi-faceted program, by supporting the implementation team with protocols and software that comply with best practices identified by implementation scientists. This addition of another layer of theory, however, exposes new knowledge gaps that require further investigation.

Understanding which components of this intervention are most efficacious is a logical objective, but nearly impossible to gauge with traditional statistical methods. Because of the complexity of the program, interwoven relationships are difficult to isolate and quantify. A feature of the 4PPTP is the customizability of practice-specific strategies. To facilitate program fidelity, participating offices are allowed to choose from a menu of evidence-based strategies within each Pillar. This flexibility allows for the alignment of the most appropriate strategies given the available implementation drivers (see Figure 4) but presents analytic challenges as all teams may not necessarily choose the same strategies. Therefore, most statistical models will be hindered by the excessive permutations of demographic variables and treatment conditions. With infinite sample size, this limitation can be overcome. However, enrolling enough PCPs in a clinical trial to ensure model stability is resource prohibitive. Similarly, strategies are not necessarily independent of one another. Some are inherently correlated, and others exhibit complex relationships with other program strategies and contextual variables in the implementation environment.

A second research and evaluation priority is the valuation of intervention strategies. Cost-effectiveness analysis, suggests that the 4 Pillars™ Program is cost-effective at the intervention level however, the relative cost-effectiveness of individual strategies has not been calculated. (86) Because of the broad range of effort required for individual strategies, understanding the return on investment for each activity would further help practices to align intervention drivers with strategy selections. Estimation of these values will be equally challenging as the actual effectiveness of each strategy is unknown.

3.0 The Expected Cost Effectiveness of the 4 Pillars™ Practice Transformation Program for Immunization in Adults 65 Years and Older

3.1 Background

The 4 Pillars™ Practice Transformation program for immunization (4PPTP) is an evidence-based immunization quality improvement intervention for primary care practices. The program was made available as an American Board of Family Medicine (ABFM) Performance in Practice Module (PPM). The cost effectiveness of its implementation is unknown.

The 4PPTP for Immunization as a multi-component immunization improvement intervention targeting primary care providers. Grounded in the recommendations provided by the Community Preventive Task Force in the *Community Guide* (87), it acts at multiple leverage points in primary care by focusing on the treatment team rather than on the patient. Additionally, the program focuses on interventions that are applicable to all vaccines and all patients rather than focusing on a single vaccine or a single age group. This provides a generalizable framework for increasing vaccination compliance throughout the lifespan. The program guides PCPs and ancillary staff in the implementation of quality improvement strategies in the domains of: 1.) convenience and access; 2.) patient communication; 3.) enhanced vaccination systems; and 4.) motivation. Custom-created software, evidence-based protocols and prolific resources were included in the program to increase adoption, ease implementation and preserve program fidelity. (41-43)

The program has undergone multiple iterations and has been evaluated in clinical trials in numerous populations. Results of these trials of the 4PPTP have shown increased uptake of

seasonal influenza vaccine in children; (44-47) meningococcal and Tdap vaccines and HPV initiation and completion in adolescents; (77, 78) seasonal influenza, pneumococcal, and pertussis vaccines in adults; (42, 48, 79) and pneumococcal vaccines in older adults. (80)

The cost effectiveness and potential public health impact of the program have also been calculated from the research data and reported for select scenarios in the US adult population. In an analysis of the cost-effectiveness of the program in US adults under age 65, the 4PPTP was estimated to be an economical option at the societal level to increase Tdap and seasonal influenza vaccinations (ICER=$31,700 QALY gained). The model predicted that extrapolating the results observed in the clinical trials to the US adult population would result in the prevention of 4.2 million cases, 87,489 hospitalizations and 5,680 deaths from influenza infection over a 10-year time horizon. If the cost per influenza case were to rise from the base case value of $846 to $2,099, the program would become cost saving at the societal level. (84) Among adults >65 years old, the program was even more cost-effective (ICER=$7,635/QALY gained) and could prevent 60,920 cases of influenza, 2,031 cases of pertussis and 13,842 cases of pneumococcal illness over the 10-year time horizon at the societal level. (85)

The patient centered medical home initiative and realignment of the nation's medical infrastructure through healthcare legislation are examples of the recent paradigm shift in medicine emphasizing prevention and effective coordination of care as key drivers of long-term health outcomes. Primary care physicians are uniquely positioned to advance this agenda by evaluating the health needs rather than treatment needs, of their patient panel. Mass vaccination is one of the most effective and important medical interventions available and ensuring every patient is appropriately immunized is reinforced by each of the primary care specialty boards.

All physicians certified by the American Board of Family Medicine (Diplomats) must provide evidence of competence, quality and continuing education to renew board accreditation. PPM are one avenue for Diplomats to demonstrate this.(88) The 4PPTP for Immunization was reviewed and accredited by the ABFM as a qualifying PPM. The program was listed online in the ABFM catalog of PPM offerings with a link to a private step-by-step version of the 4PPTP which was adapted to comply with ABFM PPM specifications. During the time that the 4PPTP was offered to ABFM Diplomats, approximately 30 physicians completed the program. Though the 4PPTP intervention could have been used with any age group of adults, the disproportionately large and vulnerable cohort of US adults over 65 years had the greatest opportunity for measurable population health impact and was therefore, selected as the population for this analysis.

Participating physicians who chose to focus on increasing vaccinations for older adults reported increased rates of vaccination for each of the available immunizations after completing the 4PPTP. Figure 9, shows the before and after rates. To evaluate whether an expanded program that achieved similar results at a national level would be economically viable, this analysis reports the potential cost effectiveness and public health impact of the 4PPTP at a societal level by modeling the costs and observed outcomes from the ABFM PPM in the United States population 65 years old and older.

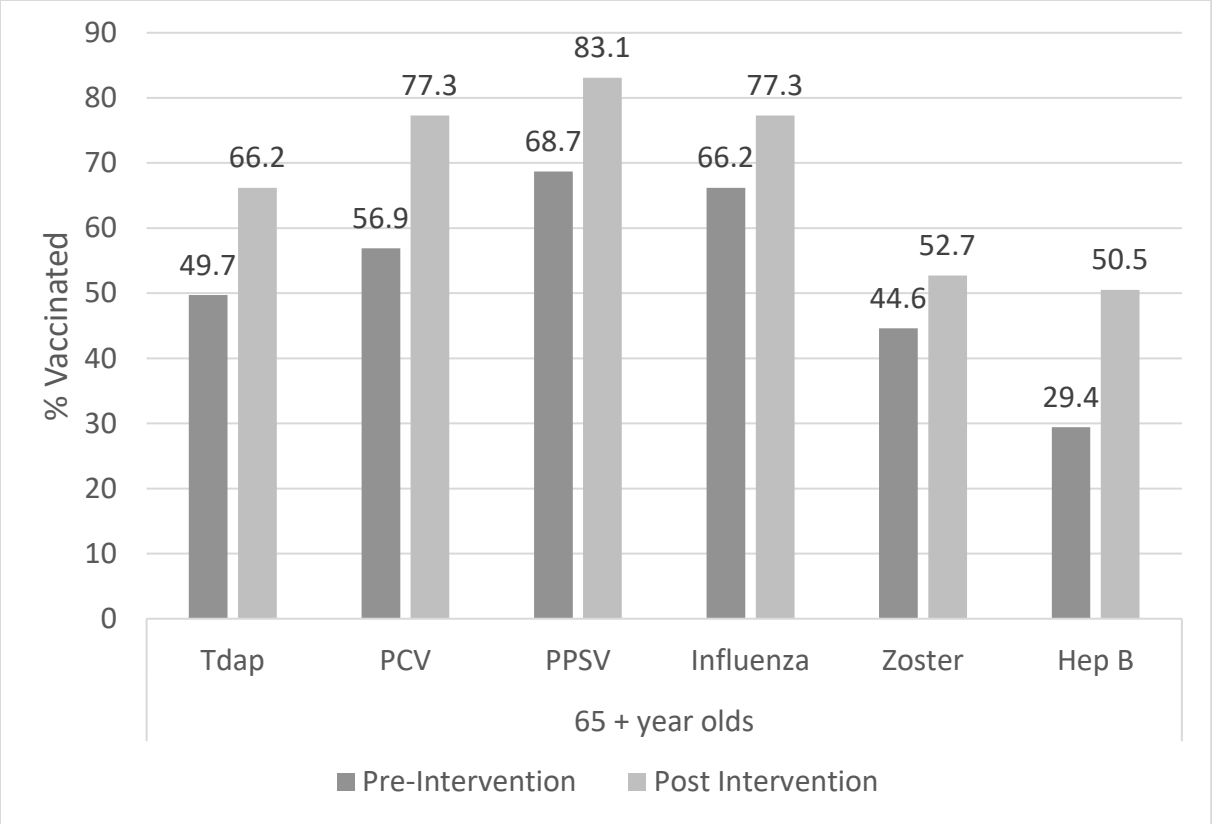

Figure 7 Pre/Post Immunization Rates by Practices Using the 4 Pillars™ Practice Transformation Program as ABFM PPM in 65+ year-old patients

3.2 Methods

To estimate the public health impact and cost-effectiveness of the 4PPTP for Immunization, a decision-tree cost-effectiveness model was constructed using TreeAge Pro Version: 2018 (64-bit), Build-Id: 18.1.1.0-v20180328. The model compared vaccination rates, health outcomes, and the costs associated with two hypothetical cohorts of US adults 65 years of age or older over 10-year time horizon whose primary care physicians were either a) exposed to the immunization intervention or b) provided standard clinical care. Intervention effects were generated by an ongoing ABFM PPM using the 4PPTP for immunization. The University of

Pittsburgh Institutional Review Board approved the analysis and data security plan (PRO17120018).

3.2.1 Vaccines

The ACIP recommends routine immunization against influenza, tetanus, diphtheria, pertussis, herpes zoster, and pneumococcal disease for all adults 65 years old or older.(89) Vaccine-specific recommendations are complicated, change frequently, and are beyond the scope of this narrative, however the general recommendations are as follows. Influenza vaccine should be administered annually. Tetanus, diphtheria, and pertussis (Tdap) vaccine should be administered once during adolescence or adulthood with Td boosters every ten years; with Tdap to replace one Td. The Zoster vaccine available during this study (Zostavax) should be administered once at age 50 years or older. The two pneumococcal vaccines, PPSV13 and PPSV23 should be administered to all adults age 65 years and older.

Though other vaccines may be indicated by patient-specific health conditions, generalizable targets can be established for the prior list of recommended immunizations. In the 65 year and older age group, the 4PPTP allows the tracking of pre/post rates for the following vaccines: influenza, Tdap, PCV, PPSV, Zoster, and Hep B. The ideal measure of immunization rates is the ratio of patients eligible for a specific vaccine who have received that vaccine to those who are eligible and have not yet received the vaccine. However, because the classification of eligibility requires access to patient health records, the 4PPTP makes no attempt to determine eligibility and computes or accepts pre/post rates as supplied by the participant. The software can compute rates from data provided during a manual review of charts from a sample of the patient

panel within the age group or can be entered directly if the rate is computed elsewhere, for example, in the electronic health record.

The pneumococcal vaccines pneumococcal conjugate vaccine (PCV) and pneumococcal polysaccharide vaccine (PPSV) present an interesting modeling challenge. As discrete vaccine administrations with non-overlapping serotype protection, they could be modeled as separate events. However, the administration guidelines which are governed by immunologic response and patient safety dictate that these vaccines should not be administered within the same year. Consequently, this relationship between the two vaccines needs to be reflected in model logic. Since the expected duration of the intervention is less than one year, the model assumes that both vaccines have been or will be administered as a two-dose series and evaluates the rate of pneumococcal vaccination as the average of the PCV and PPSV rates.

Accurately measuring influenza vaccination rates as flu season begins or ends can also become problematic. If the intervention spans either time, determining eligibility is nuanced. For example, should a practitioner consider a non-immunized patient eligible or ineligible on April 1? Such a determination requires knowledge of the prevalence of the annual epidemic. This model assumes that participants will naturally avoid this issue by not targeting influenza improvement when the intervention is conducted outside of the annual flu season.

Zoster vaccination policy presents additional modeling challenges in the study population. The tabulation of Zoster rates seems to be the most straight-forward computation. However, this apparent simplicity is undermined by provider and/or patient behavior. The high cost of the vaccine and complicated reimbursement schemes frequently result in a referral to pharmacies for administration. In these cases, the administration may not be recorded in the medical record or the

patient may fail to follow up on the referral. As with influenza, this model assumes that physicians who are not prepared to administer zoster, will not choose to target the rate for improvement.

Computing zoster-related parameter estimates was an additional complication addressed in this analysis. Zoster vaccine has been recommended for healthy adults 60 years of age and older.(90) This recommendation is logical given the presentation of the disease but a non-typical cohort for epidemiologic analysis. Therefore, model parameters for 60-65-year-old individuals, were developed by applying age-specific data reported in early clinical trials of the vaccine with epidemiologic surveillance data typically reported in two cohorts of adults divided at age 65 years. These transformations and assumptions are described further below.

Vaccination costs are also readily available. The annual vaccine price list published by the Centers for Disease Control (CDC) and a search of the Centers for Medicaid Services (CMS) physician fee schedule report the required parameters for both the CDC contract and private sector prices.(91, 92) The public contract price is used for all public insurance programs (i.e. Medicaid and Medicare) and grant-funded immunization efforts. Private sector costs are reported annually to the CDC by vaccine manufacturers. As vaccination of nearly all US seniors is covered by Medicare, the model uses CDC contract prices.

3.2.2 Disease Dynamics

The 4PPTP does not alter the outcomes associated with infection directly. Rather, the program seeks to prevent cases of disease through increased vaccination. This model compares the incremental costs and benefits of a national implementation of the program over a 10-year time horizon. This duration corresponds to the ages 65-75 years where parameter estimates are most

stable. As individuals age beyond 75 years old, vaccine effectiveness is less consistent and robust due to comorbid conditions and immunesenescence.(93, 94)

Routine population surveillance provides estimates of disease prevalence. Though immunologic response can be individually variable and can impact susceptibility, it was assumed that prevalence is generally consistent over time and predicted by vaccine uptake. In the base case, the model used the prevalence of disease observed in prior seasons. In the experimental case, prevalence is adjusted by the increase or decrease of vaccine coverage attributed to the intervention.

The consequences of infection by each VPD are well-studied. Estimates of the likelihood of disease-specific complications are available in pre-licensure vaccine effectiveness (VE) studies and frequently can be derived from population surveillance data as well. The model considers each outcome as a binary decision where the probability of each complication is governed by Bayesian inference. Outcomes in this model, are assumed to be independent of factors that cross VPD and are attributed solely to the natural progression of disease and intervention effects. For example, infection by one VPD is assumed to be unrelated to infection by other VPD.

In addition to monetary costs associated with VPD, disease prevention strategies, treatments and outcomes are also parameterized by their experiential cost expressed as the increase or decrease of quality adjusted life years (QALY). This analysis uses a weighted average life expectancy for the 65 year and older cohort from US census cohort age distributions.(95) All QALY adjustments for modeled factors are made relative to this baseline value. Some factors (for example, receiving a vaccine) have a minimal QALY cost per individual as the procedure requires little time and inconvenience. Other factors (for example, death) have a potentially large QALY

cost as the reduction of life years is absolute. Values for each factor included in the model were available from the literature.

3.2.3 Intervention Dynamics

At the clinical level, the 4PPTP operates through multiple pathways simultaneously however, these intra-intervention dynamics were not modeled. Because participants are allowed to customize the intervention, capturing the effect of any single intervention strategy is impractical. Moreover, modeling the interactive dynamics among selected strategies would not necessarily add clarity to the outcome in the form of the incremental cost effectiveness ratio. These effects were assumed to be captured in the cost of the intervention and the increase or decrease in vaccination rates. Therefore, the experimental condition differed from the base case only in vaccination uptake.

To estimate the effect of the intervention, the observed differences in pre/post rates of vaccination from the ABFM PPM intervention were added to the base case vaccination rates. The modified values were substituted as the experimental probability of vaccination in the alternative strategy arm. All other dynamics were identical between arms.

3.2.4 Simulation Environment

The analysis uses the societal perspective following the guidelines for cost-effectiveness analyses by the Second US Panel on Cost-Effectiveness in Health and Medicine.(96) Relevant health effects and costs occurring during the time horizon were included in the model regardless of payor. Secondary effects such as herd immunity and non-healthcare outcomes including alterations to productivity, consumption and outcomes in other economies were not modeled. Non-

monetary costs such as the perceived inconvenience of disease and complications were aggregated through utility values into a net change in quality adjusted life years.

The primary analytic outcome was the incremental cost effectiveness ratio (ICER) which represents the difference between the cost per QALY of the intervention arm and the reference arm. The evaluation of cost-effectiveness for each strategy was computed as the ratio of the sum of the accrued costs of the program, vaccination and illnesses to the sum of the accrued QALY lost for the same. Prior to analysis, a willingness to pay value of $100,000 per QALY was accepted as the threshold for a determination of cost effectiveness for the favored strategy. Thus, the intervention would be considered a good value at a societal level if its ICER were greater than the base case and if the program cost less than $100,000 per QALY. The study population was composed of two identical hypothetical cohorts of greater than 65-year-old US adults. Population characteristics including age distribution and life expectancy were extracted from US census data.

The complete model and supporting documentation are available online at https://github.com/PittVax/4PillarsCEA_over65. As shown in a simplified diagram of the decision tree in Figure 8, the two cohorts entered the model with the assignment of vaccination status for each vaccine. The proportion of individuals receiving each combination of vaccines was computed using the product of the fractional probabilities of accepting each vaccine. Likelihood values for influenza, pertussis and herpes zoster vaccination required no transformations. Likelihood of pneumococcal vaccination was modeled as the average of the probabilities of receiving PCV and PPSV.

Only the likelihoods of vaccination differed between the arms. In the intervention arm, the observed average percentage point increase/decrease from baseline in the ABFM PPM data was added to rates used in the reference arm. After vaccine status was assigned, infection from each

illness was determined using reported VE and the annual likelihood of infection computed for each VPD. All related health outcomes were assessed for those infected. Outcomes for each branch were computed as the ratio of the sum of the costs associated with: the program, illnesses, complications, and vaccinations to the sum of QALY lost.

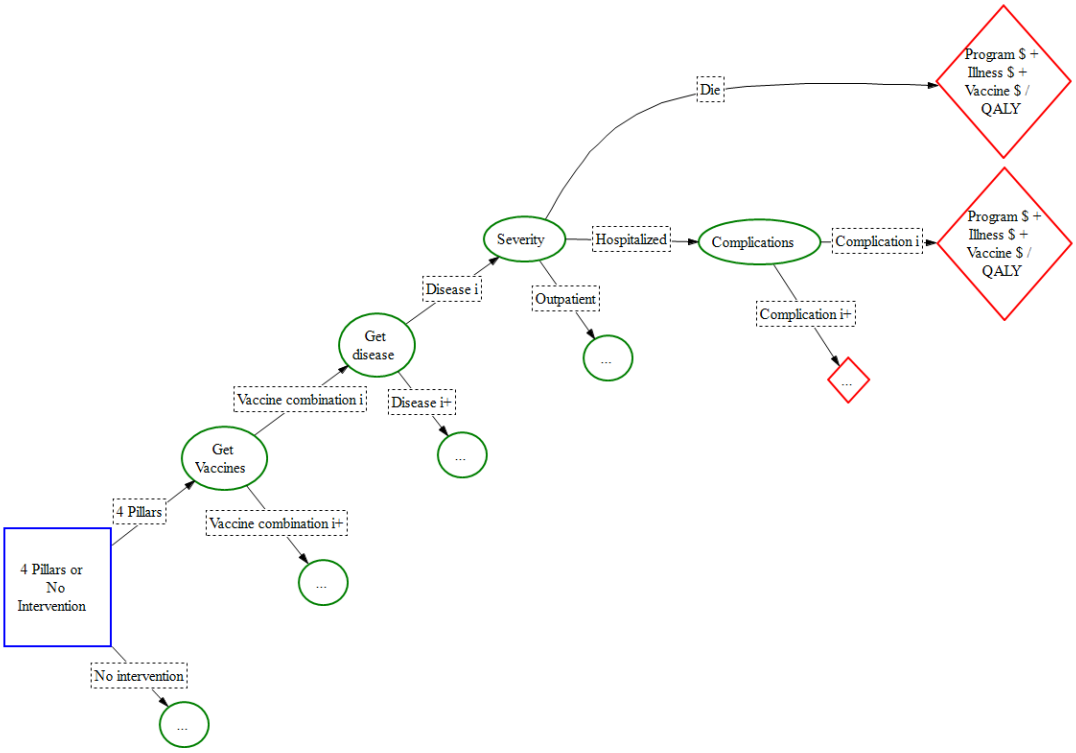

Figure 8 Simplified View of Tree Structure

3.2.5 Model Parameters

Model parameter values were sourced from public databases and the medical economic literature as enumerated in Table 3. When appropriate, values were converted to a reference year of 2015 and future values were discounted at 3% per year. All parameters were varied widely in sensitivity analyses. Monetary costs of the program, vaccinations, illnesses and complications were measured in 2015 US dollars. Non-monetary outcomes were measured in QALY lost.

Table 2 Model Parameters

	Value	Low	High	Distribution	Reference
Costs (base year 2015), $					
Disease					
Herpes zoster					
Acute - inpatient	8745.24	7923.63	10195.49	Gamma	(97)
Acute - outpatient	348.30	268.21	512.14	Gamma	(97)
Herpes zoster oticus	433.26	121.36	849.52	Gamma	(97)
Ocular complications	13659.12	11231.91	16086.33	Gamma	(97)
Post-herpetic neuralgia	686.90	586.17	816.76	Gamma	(97)
Influenza					
Influenza (average, all severities)	1655.00	432.00	3706.00	Gamma	(85)
Pertussis					
Mild pertussis, when treated	305.00	153.00	1525.00	Gamma	(85)
Moderate pertussis	424.00	212.00	2120.00	Gamma	(85)
Severe pertussis	7824.00	4000.00	11500.00	Gamma	(85)
Pneumonia					
Invasive pneumococcal disease					
Disabled	32795.00	26236.00	39354.00	Gamma	(98)
Invasive pneumococcal disease	26031.72	20825.00	31238.00	Gamma	(98)
Nonbacteremic pneumococcal pneumonia					
Hospitalized	16671.00	13337.00	20005.00	Gamma	(98)
Outpatient	587.00	470.00	704.00	Gamma	(98)
Implementation program, per eligible person	1.78	0.70	2.26	Gamma	(85)
Vaccines					
Herpes zoster - Zostavax	187.89	150.00	225.00	Gamma	(99)
Influenza - Fluzone	10.69	6.64	32.75	Gamma	(85)
Pneumococcal conjugate - Prevnar 13 TM	159.60	96.10	220.00	Gamma	(85)
Pneumococcal polysaccharide - Pneumovax23	78.90	26.60	130.00	Gamma	(85)
Tdap - Boostrix	37.55	20.18	42.61	Gamma	(85)
Vaccine administration, per vaccine	25.51	20.00	30.00	Gamma	(85)

Table 2 Continued

Duration, Days					
Herpes zoster					
Acute infection	21.00	14.00	28.00	Poisson	(100)
Hospitalization	4.80	4.50	5.40	Poisson	(97)
Post herpetic neuralgia	60.00	30.00	120.00	Poisson	(100)
Pertussis	87.00	30.00	100.00	Poisson	(85)
Pneumonia					
Invasive pneumococcal disease	27.00	20.00	40.00	Poisson	(85)
Nonbacteremic pneumococcal pneumonia					
Hospitalized	27.00	20.00	40.00	Poisson	(85)
Outpatient	18.00	10.00	25.00	Poisson	(85)
Probabilities					
Herpes zoster					
Case-mortality per 100,000	10.16	5.08	15.24	Beta	(101)
Complications					
Any ophthalmic complications	0.0220	0.0120	0.0320	Beta	(97)
Herpes oticus	0.0020	0.0000	0.0050	Beta	(97)
Monaural deafness, given herpes oticus	0.0690	0.0130	0.1200	Beta	(97)
Monocular blindness, given ophthalmic complications	0.0390	0.0110	0.0670	Beta	(97)
Post herpetic neuralgia >70	0.5600	0.3500	0.7500	Beta	(97)
Hospitalization	0.0180	0.0050	0.0680	Beta	(102)
Influenza					
Case-hospitalization	0.0421	0.0140	0.0700	Beta	(85)
Case-mortality per 100,000	1170	370	2000	Beta	(103)
Pertussis					
Relative likelihood of treatment (vs no treatment)	0.7070	0.5000	0.9000	Beta	(85)
Severity relative likelihood					
Encephalopathy, given severe	0.0143	0.0000	0.0300	Beta	(85)
Moderate	0.7400	0.6300	0.8500	Beta	(85)
Mortality, given severe	0.0086	0.0000	0.0200	Beta	(85)
Severe (hospitalized)	0.1200	0.0600	0.1800	Beta	(85)

Table 2 Continued

Pneumonia					
Invasive pneumococcal disease					
Case-mortality	0.2000	0.1000	0.3000	Beta	(98)
Disabled	0.0610	0.0305	0.0915	Beta	(98)
Nonbacteremic pneumococcal pneumonia					
Case-mortality	0.0730	0.0365	0.1095	Beta	(98)
Relative likelihood of outpatient treatment (vs inpatient)	0.8310	0.7000	0.9600	Beta	(85)
Probability of illness without vaccinations (yearly)					
Herpes zoster	0.0114	0.0050	0.0160	Beta	(104)
Influenza	0.0900	0.0660	0.1140	Beta	(103)
Invasive pneumococcal disease	0.0002	0.0000	0.0007	Beta	(85)
Nonbacteremic pneumococcal pneumonia	0.0378	0.0054	0.1210	Beta	(85)
Pertussis	0.0026	0.0014	0.0046	Beta	(85)
Probability of vaccination					
Absolute increase in vaccine uptake with program					
Herpes zoster	0.0802	0.0000	0.1203	Beta	Data
Influenza	0.1116	0.0000	0.2200	Beta	Data
Pneumococcal vaccines	0.1742	0.0000	0.3400	Beta	Data
Tdap	0.1654	0.0000	0.2200	Beta	Data
Before program					
Average of PCV PPSV	0.6279	0.3100	0.8090	Beta	Data
Herpes zoster	0.4464	0.2200	0.6600	Beta	Data
Influenza	0.6616	0.3600	0.7400	Beta	Data
Tdap	0.4965	0.2500	0.7500	Beta	Data
Disutilities (QALY lost)					
Illness death (discounted)	10.25	5.00	15.00	Gamma	(85)
Influenza					
Hospitalized	0.042	0.020	0.08	Gamma	(85)
Outpatient	0.002	0.00	0.02	Gamma	(85)
Utilities					
Pertussis					
Mild	0.90	0.99	0.80	Gamma	(85)
Moderate	0.85	0.95	0.75	Gamma	(85)
Severe	0.81	0.90	0.60	Beta	(85)

Table 2 Continued

Herpes zoster					
Acute - outpatient	0.022	0.011	0.03	Beta	(97)
Monaural deafness	0.97	0.96	0.98	Beta	(97)
Monocular blindness	0.92	0.88	0.96	Beta	(97)
Post herpetic neuralgia	0.67	0.63	0.70	Beta	(97)
Nonbacteremic pneumococcal pneumonia					
Disability post pneumococcal disease	0.40	0.20	0.60	Beta	(85)
Inpatient	0.20	0.00	0.50	Beta	(85)
Invasive pneumococcal disease	0.20	0.00	0.50	Beta	(85)
Outpatient	0.90	0.70	1.00	Beta	(85)
Pertussis					
Encephalopathy	0.20	0.00	0.40	Beta	(85)
Vaccine effectiveness					
Influenza	0.59	0.20	0.67	Beta	(85)
Pneumococcal illness serotype prevalence					
13-valent pneumococcal conjugate vaccine serotypes	0.31	0.00	0.50	Beta	(85)
23-valent pneumococcal polysaccharide vaccine serotypes	0.68	0.50	0.85	Beta	(85)
Pneumococcal vaccines (10-year average)					
Invasive pneumococcal disease	0.54	0.40	0.68	Beta	(85)
Nonbacteremic pneumonia	0.38	0.28	0.48	Beta	(85)
Tdap (10-year average)	0.25	0.00	0.95	Beta	(85)
Zoster	0.26	0.13	0.38	Beta	(102)

3.2.5.1 Costs

The costs associated with each VPD were found in the literature. Likelihood of infection was assumed to be related only to vaccination and vaccine effectiveness and assumed to be uncorrelated with other infections. Influenza infection could result in outpatient treatment, hospitalization, or death. Recovered individuals were assumed to suffer no long-term complications. Pneumococcal disease was modeled in two branches. Invasive pneumococcal disease (IPD) resulting in outpatient treatment, hospitalization and disability or death and non-

bacteremic pneumococcal pneumonia (NPP) which could lead to outpatient treatment or hospitalization and recovery, disability or death. Pertussis resulted in mild and moderate infections with recovery, or severe infections leading to recovery, encephalopathy or death. Finally, Zoster infection was modeled with branches for outpatient treatment, hospitalization and complete recovery, hospitalization and death, or hospitalization and recovery with complications including post-herpetic neuralgia, monocular blindness and monaural deafness.

Program costs were estimated through a survey of participants in a randomized controlled trial of the 4PPTP who valued the personnel and material costs associated with the intervention.(85) Though the self-directed ABFM PPM version of the program was of a shorter duration and required no interaction with the program administrators, costs were assumed to be equal to those of the clinical trial. This conservative assumption biases against the value of the intervention.

As most of the vaccines administered to older adults are paid by Medicare, the CDC contract price of each vaccine, except zoster, was used for vaccine cost. The private sector price was used for Zoster which is only covered by Medicare part D and has complex reimbursement guidelines which often result in patients 65 years and older paying retail cost for the vaccine. Over the 10-year time horizon, Tdap and Zoster vaccine are charged once. Influenza vaccine is charged annually and discounted at 3%. The pneumococcal vaccines PCV and PPSV are assumed to be given in a two-dose series resulting in two administration fees and the cost of each vaccine for those who receive the vaccine. Co-administration of vaccines would reduce the cost of the intervention. Therefore, to bias against the intervention, vaccines were assumed to be administered individually and assigned an administration fee per vaccine.

3.2.5.2 Probabilities

Vaccines

Vaccination probabilities, as presented in Table 3, were assigned using the data generated by participants in the ABFM PPM. Each subject is a physician leading a clinical practice through the implementation of the 4PPTP module in their 65 year and older patient panel. During enrollment, physicians chose which vaccines would be used as measures of quality improvement from the list of vaccines indicated for the selected patient age group. Following vaccine selection, physicians entered a baseline rate for each vaccine. At the end of the intervention, physicians entered a post-intervention rate for each selected vaccine.

Table 3 ABFM PPM pre/post immunization rates by vaccine in 65+ year-old patients

Vaccine Type	Pre-Intervention	Post Intervention	Percentage Point Change	N
Tdap	49.7	66.2	16.5	29
PCV	56.9	77.3	20.4	34
PPSV	68.7	83.1	14.4	26
Influenza	66.2	77.3	11.1	28
Zoster	44.6	52.7	8.1	26

The model uses pre-intervention rates as the likelihood of vaccination in the no-intervention arm and adds the absolute percentage point change to these values in the experimental arm. This method allows for more plausible sensitivity testing as the experimental condition is varied relative to the baseline value. If the post-intervention rates were directly assigned to the intervention arm, sensitivity testing would evaluate improbable differences in before/after measurements. As noted above, in the absence of individual patient records, PCV and PPSV were modeled as a two-dose series with rates computed as the average of the baseline (0.6279) and follow-up (0.8021) vaccination rates. For patients in the branches where pneumococcal vaccine

was assigned, it was assumed that both vaccines would be administered. This assumption was tested widely in sensitivity analyses.

The likelihood of infection for the population in each branch was determined by evaluating vaccination status and then applying protection through vaccine effectiveness on appropriate branches. Table 4 shows a truth matrix for the 16 possible branches. The overall probability for each combination of vaccines was determined by calculating the product of the individual probabilities of receiving each vaccine. For example, the likelihood of receiving all four vaccines is expressed as follows:

$$p_{All\ vaccines} = p_{Flu} * p_{Tdap} * p_{pneumo} * p_{zoster}$$

The likelihood of receiving none of the four vaccines is expressed as follows:

$$p_{No\ vaccines} = (1 - p_{Flu}) * (1 - p_{Tdap}) * (1 - p_{pneumo}) * (1 - p_{zoster})$$

Table 4 Truth table of vaccination status

Vaccines	Influenza	Tdap	Pneumococcal	Zoster
None	No	No	No	No
Zoster	No	No	No	Yes
Pneumococcal	No	No	Yes	No
Pneumococcal, Zoster	No	No	Yes	Yes
Tdap	No	Yes	No	No
Tdap, Zoster	No	Yes	No	Yes
Tdap, Pneumococcal	No	Yes	Yes	No
Tdap, Pneumococcal, Zoster	No	Yes	Yes	Yes
Influenza	Yes	No	No	No
Influenza, Zoster	Yes	No	No	Yes
Influenza, Pneumococcal	Yes	No	Yes	No
Influenza, Pneumococcal, Zoster	Yes	No	Yes	Yes
Influenza, Tdap	Yes	Yes	No	No
Influenza, Tdap, Zoster	Yes	Yes	No	Yes
Influenza, Tdap, Pneumococcal	Yes	Yes	Yes	No
Influenza, Tdap, Pneumococcal, Zoster	Yes	Yes	Yes	Yes

Infection was determined according to each disease's attack rate in the population aged 65 years and older. Protection from illness through vaccination was included for appropriate branches by multiplying the illness attack rate by one minus VE. Illness probabilities were transformed to annual probabilities where necessary by converting to rates, adjusting by the 10-year time horizon and then converting to annual probabilities.

Attack rates and vaccine efficacies for influenza, pneumococcal disease and pertussis in the population were found in recently published estimates in the medical literature.(85) As with other herpes Zoster parameters, attack rate and VE were not available for the study population. To maintain consistency with the same decision for VPD-related illness outcomes, estimates for the 70 year-old and older population were used.(104) The pneumococcal vaccines PPSV and PCV13 offer protection for different viral serotypes which circulate at different rates in the population. It was assumed that PPSV offered protection against IPD and PCV13 against IPD and NBP. Though the likelihood of receiving either vaccine was averaged into a combined probability for pneumococcal vaccination, the individual efficacies and attack rates for IPD and NBP were used in assessing health outcomes. These assumptions were tested in sensitivity analyses. The efficacies of zoster, pertussis and pneumococcal vaccines have been shown to decline with increasing patient age.(105-109) This dynamic was included in the analysis by calculating average VE for the vaccines over the 10-year time horizon.

Health outcomes

When available, probability estimates were sourced from prior peer-reviewed modeling studies. However, estimates of zoster-related probabilities were unavailable in the study population. As noted earlier, the clinical trials which report the parameters for cost effectiveness modeling were conducted in a cohort of individuals selected by medical indication (>= 60

years)(104) rather than by the common demographic age definition for older adults (>=65 years). Consequently, these values incorporate the greatest number of assumptions.

Because acute herpes zoster is rarely fatal, clinical trials of Zoster mortality in alternative cohorts would be cost-prohibitive and unlikely to yield significant information. In the absence of this epidemiologic data, zoster-related mortality was extracted from the CDC WONDER underlying causes of death database. For individuals 65-74 years in 2015 (27,550,517), 32 deaths included one or more of the ICD-10 codes: B02.0 (Zoster encephalitis), B02.1 (Zoster meningitis), B02.2 (Zoster with other nervous system involvement), B02.3 (Zoster ocular disease), B02.7 (Disseminated zoster), B02.8 (Zoster with other complications), B02.9 (Zoster without complication).(110) Cases over age 74 years were excluded as the model time horizon is limited to 10 years.

Prior cost-effectiveness studies of hypothetical herpes zoster vaccination strategies by age provided values for additional parameters by applying outcomes from observational studies and retrospective medical claims data analyses to age-stratified cohorts.(97) Herpes zoster complications included probabilities of ophthalmic complications (0.022), monocular blindness, given ophthalmic complications (0.039) herpes oticus (0.002), monaural deafness, given herpes oticus (0.069), and long-term post herpetic neuralgia (0.560).

To facilitate comparison with observational data generated from the Shingle Prevention Study, (104) Rothberg, Virapongse (97) developed probability estimates for post herpetic neuralgia for the 60-69 and 70 year and older cohorts from data provided by a retrospective medical database extraction study. They noted that the estimates describing the younger cohort differed from those observed in the clinical trial. Therefore, the older population estimate was used in this model. Likewise, as developed in another study using similar methods, the probability of

hospitalization due to herpes zoster among those 70-79 years (0.018) was selected over the alternative (0.013) for those 60-69 years. (102)

Well-documented estimates of other event probabilities for the population 65 years and older were available in the literature. Beginning with infection, each illness branch included the probability of developing clinically relevant sequela leading to either death or recovery. Death resulting from each illness is modeled as case-mortality within one year of infection. Survival was calculated as the complement to the Bayesian combination of all other outcomes. For example, given influenza infection, outpatient treatment and recovery (p=0.946) is the probability remaining after subtracting the probability of hospitalization and recovery (p=0.042) and hospitalization and death (p=0.012) from the total probability of any event (p=1.0).

A statistical analysis of data reported from the National Center for Health Statistics and the National Hospitalization Discharge Survey Estimates provided probabilities of influenza-related outcomes. This analysis extended an established Poisson fitting algorithm(111) to a more sensitive sub-set of ICD-10 codes which was then fitted to a peri-season risk-difference model resulting in a point estimate of annual influenza case-fatalities of 1170 per 100,000, and a probability of hospitalization of 0.018. (103)

Pneumococcal disease included two variations. Estimates of invasive pneumococcal disease (IPD) and nonbacteremic pneumococcal pneumonia (NBP) outcomes were compiled from simulation data provided with a cost-effectiveness analysis of 13-valent pneumococcal conjugate vaccine (PCV13).(98) Though more complex, using simulation output rather than observational data was necessary to cover all probabilities with more granularity than could be achieved with less specific clinical data. As is reflected in the data, the severity of a given pneumococcal infection is related to the patient's overall health status. Thus, weighted averages for each clinical outcome

were calculated using the data stratified into low, medium and high-risk patient groups. Table 5 summarizes the relevant values and computations. First, the total IPD rate was evaluated for each risk group by multiplying the population in each risk group by the sum of the bacteremia and meningitis rates. Next, the individual rates were used to generate the number of cases of meningitis and bacteremia in each risk group. These values were multiplied by the mortality rates to arrive at expected case-fatalities due to IPD.

Table 5 Estimated invasive pneumococcal disease case-fatalities by risk group in 65-74 year old individuals

	65–74 years		
	Low Risk	**Moderate Risk**	**High Risk**
No. of US adults (in millions)	8.8	8	4.1
Annual disease incidence (per 100,000)			
Bacteremia rate	4.30	16.90	69.00
Meningitis rate	0.30	1.10	4.40
IPD rate	4.60	18.00	73.40
IPD cases	405	1440	3009
Bacteremia			
Cases	378	1352	2829
Mortality	0.138	0.172	0.207
Case-fatalities	52	233	586
Meningitis			
Cases	26	88	180
Mortality	0.235	0.293	0.352
Case-fatalities	6	26	64
Total IPD case-fatalities	58	258	649

Finally, the sum across the row for total IPD cases (4854) was divided by the sum across the row for total IPD case-fatalities (966) to obtain the weighted probability of death (0.20) due to invasive pneumococcal disease. Similarly, the weighted average of meningitis cases was calculated and used as the probability of IPD hospitalized recovery with disability (0.06). Infection

by IPD was assumed to include hospitalization, thereby assigning the hospitalized and recovered branch the remaining probability.

3.2.5.3 Utilities and Durations

Effectiveness was quantified through utility estimates. This strategy transforms each potential health state to a proportion of quality adjusted life years (QALY) to expected full quality life. For example, the utility of each herpes zoster complication was estimated in the randomized clinical trial of vaccine effectiveness where patients recorded daily pain using the worst-pain component of the herpes zoster brief pain inventory. (97) Investigators derived a total adjustment in quality of life for each condition, by statistically relating the zoster-specific pain measurements to the validated EuroQOL-5D inventory of patient utilities and then dividing the observation period by one year. The estimates show that post-herpetic neuralgia (PHN) is the most offensive non-fatal herpes zoster outcome and results in a quality adjustment of 0.67 of life quality. Similarly, acute outpatient infection is the least objectionable herpes zoster condition resulting in a quality adjustment of only 0.0216.

Total effectiveness for each branch was calculated as the sum of QALY lost due to adverse health conditions in the branch. This computation required assigning an expected duration to each complication and then adjusting that time by the utility value. In this strategy, utility values are transformed to disutilities where $Disutility = 1 - \text{utility}$ and then converted to QALY with $Disutility * {days\ of\ condition}/{365} = \text{QALY lost}$ For PHN, a utility of 0.67 (disutility of 0.33 with 60 day duration) represents a reduction of 0.05 QALY or 19.8 days of a full quality life. As with other time-based measurements, it is necessary to discount future values. Each effectiveness estimate was discounted at 3% per year and assigned to appropriate branches.

Mortality was modeled with an identical strategy. The disutility of fatal outcomes was modeled as 100% loss of QALY over the duration of death where duration of death represented the life expectancy of the cohort. Life expectancy (77.19 years) was calculated as the weighted contribution of each year of life to total life years reported by the 2015 US census for the population 65 years and older. Non-fatal chronic outcomes were assumed to endure over this remaining life expectancy.

3.2.5.4 Sensitivity Analyses

All parameters were subjected to sensitivity analysis over a broad range of values. In the deterministic base case analysis, high and low values were assigned to each parameter value as shown in Table 3. When possible, these values were extracted from the literature along with the parameter estimate. When unavailable, these values were calculated as ±20%-50% around the point estimate in accordance with the uncertainty of each estimate. The impact of each input was calculated by varying parameters individually and then computing the model for each value in the range. This technique estimates the total variability in model outcomes attributable to each parameter.

A probabilistic sensitivity analysis was also conducted. This analysis varies all parameters with each calculation of the model. As shown in Table 6 an appropriately shaped distribution was assigned to each parameter type as recommended by the Panel on Cost-Effectiveness in Health and Medicine. (112) Each of these distributions was fit to the base case ranges by specifying a mean distribution location near the point estimate and a distribution spread covering the low and high range. The model was then run using parameter values randomly sampled from the associated distribution.

Table 6 Appropriate distributions by variable type for probabilistic sensitivity analysis

Parameter Type	Distribution
Costs	Gamma
Utility/Disutility **Probability** **Proportion** **Efficacy**	Beta
Quantity	Poisson

The output from these preliminary runs was compared to the base case parameter values and distribution specifications were adjusted as necessary to match base case parameter ranges as closely as possible. A final run of 500 iterations using 500 sets of randomly selected values generated the average expected incremental cost-effectiveness ratio (ICER) for the two arms produced by each simulation.

3.3 Results

The 4PPTP was favored over the No-Program condition with an estimated cost per QALY of $4,927.10. In sensitivity testing, the model showed no threshold effects where individual parameters would be likely to alter the favorability of the strategies. Table 7 shows the incremental cost effectiveness ratio of the 4PPTP vs. No Program. The program cost was $32.63 more than standard treatment and saved 0.0066 QALY per individual at a value of $4927.10 per QALY saved.

Table 7 Base Case Cost effectiveness of the 4 Pillars™ Practice Transformation Program vs. No Program

	Cost ($)	Effectiveness (QALY)	Incremental Cost ($)	Incremental Effectiveness (QALY)	ICER ($/QALY)
No program	1998.54	-0.1094	0.0000	0.0000	0.0000
Implementation program	2031.17	-0.1028	32.63	0.0066	4927.10

The predicted public health outcomes of the program are listed in Table 8. The model suggests that if the program were applied to a population resembling the 2015 US cohort of individuals 65 years of age or older, over 2.38 million cases of disease, 163,280 hospitalizations and 27,736 deaths would be averted over the 10-year time horizon.

Table 8 Public health outcomes of 4 Pillars™ Practice Transformation Program for 65+ population over 10-year time horizon

		Expected Cases	Averted Cases
VPD	Condition		
Influenza	cases	17,778,792	-1,920,143
	hospitalizations	956,499	-103,304
	deaths	208,012	-22,466
Pertussis	cases	1,060,743	-48,430
	cases (mild)	148,504	-6,780
	cases (moderate)	786,044	-35,888
	cases (severe)	127,289	-5,812
	deaths	1,095	-50
Pneumo NPP	cases	14,058,218	-302,194
	outpatient	11,682,379	-251,123
	hospitalizations	2,375,839	-51,071
	deaths	173,436	-3,728
Pneumo IPD	cases	84,123	-6,935
	hospitalizations	84,123	-6,935
	deaths	16,825	-1,387

Table 8 Continued

Zoster	cases	4,572,212	-103,739
	outpatient	4,485,354	-101,768
	hospitalizations	86,859	-1,971
	HO deafness	630	-14
	blindness	3,919	-89
	PHN	2,557,839	-58,035
	deaths	4,642	-105

3.3.1 Sensitivity Analysis

In one-way sensitivity testing, the model was very stable with no features resulting in dominance of the experimental arm. This result is pictured in Figure 9, a tornado diagram of the features with cumulative risk > 99%.

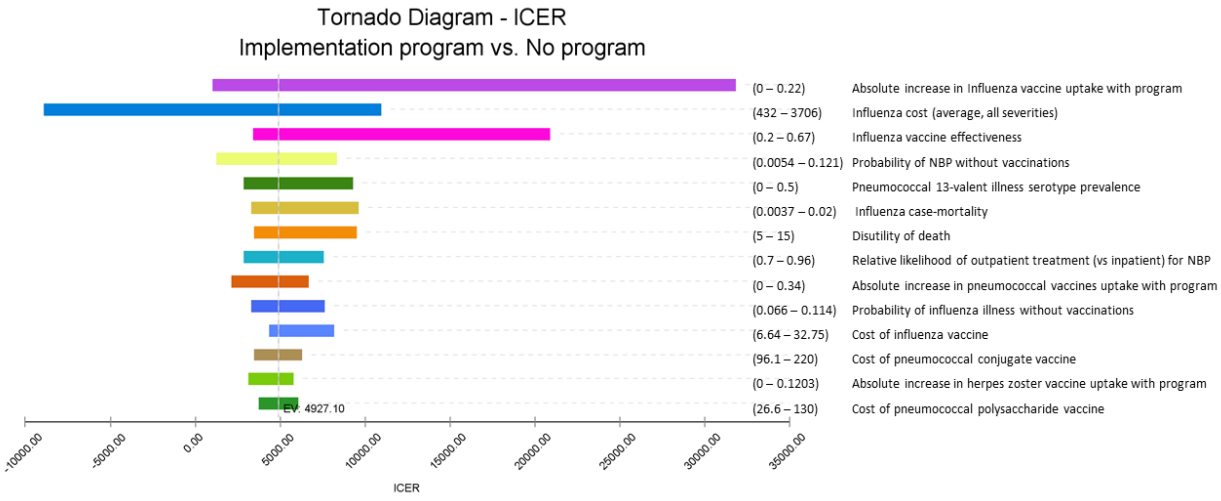

Figure 9 Tornado Diagram of ICER for Implementation Program vs. No Program X axis = willingness to pay per QALY, bands = uncertainty by parameter

Fourteen features account for 99% of the variability in the model with the top five features representing 90% of uncertainty. Influenza-related parameters produced the largest variability in outcomes with the absolute increase in influenza vaccine uptake with the program potentially

increasing the ICER to $31,826/QALY and average influenza illness costs potentially reducing the ICER to -$8,905/QALY making the program cost-saving. Influenza vaccine effectiveness was also a key driver of cost potentially raising the ICER to $20,894/QALY when the vaccine is least effective. Case-mortality, virulence and vaccine cost also contribute to the 89% of variance attributable to influenza-related factors.

Pneumococcal disease drives the second most influential cluster of factors. The total uncertainty from this cluster accounts for 7.6% of potential variability in the ICER and no single factor would be likely to shift the intervention to cost saving. Similar to influenza, epidemiologic factors (NBP virulence and 13-valent prevalence), treatment costs (NBP severity, vaccine costs) and increases in pneumococcal vaccination rates contribute to potential changes in the ICER. Combined, the estimation of the disutility of death and changes in herpes zoster vaccination rates account for 2.3% of uncertainty in the ICER. Neither factor would be likely to change the favorability of the program.

A Monte Carlo probabilistic sensitivity analysis was conducted. Over 500 iterations, the program was the favored strategy with an average cost per QALY of $3,846.09 as shown in Table 9. The cost estimation for the implementation program strategy ranged from $1,087.75 to $3,690.19 (median = $1,899.08) and $1,021.34 to $3,732.54 (median=$1,861.36) for the no-program strategy. Effectiveness estimates ranged from -0.2818 to -0.0348 (median= -0.0960) for the 4PPTP strategy and -0.2945 to -0.0428 (median= -0.1036) for the no-program strategy.

Table 9 Cost effectiveness of the 4 Pillars™ Practice Transformation Program vs. No Program from Monte Carlo Simulation

	Cost ($)	Effectiveness (QALY)	Incremental Cost ($)	Incremental Effectiveness (QALY)	ICER ($/QALY)
No program	1923.42 (SD=397.13)	-0.1066 (SD=0.0271)	0.0000	0.0000	0.0000
4PPTP	1950.82 (SD=382.86)	-0.0995 (SD=0.026)	27.39	0.0071	3846.09

Over the 500 iterations, the intervention arm was strongly favored for all willingness-to-pay values above $20,000. The cost effectiveness acceptability curve shown in Figure 10 displays minimal uncertainty in the model outcomes across the simulation suggesting that the model would predict similar results even when base case parameters are altered within expected ranges.

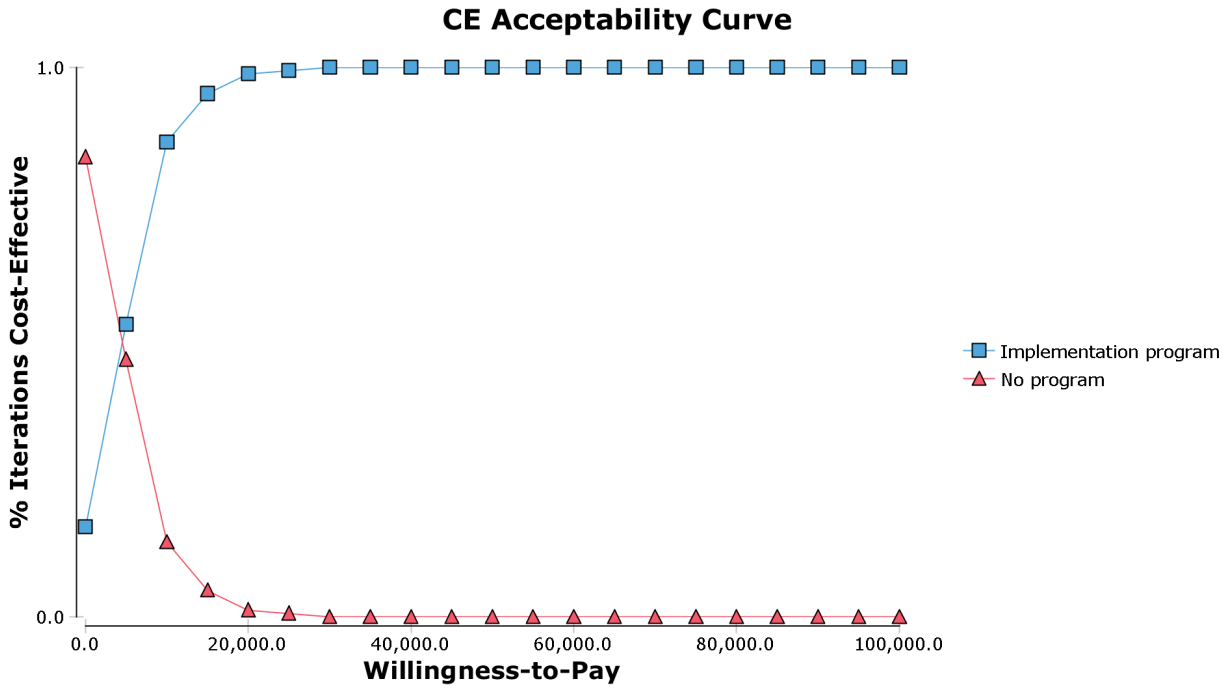

Figure 10 Cost effectiveness acceptability curve of Monte Carlo simulation results showing the number of iterations where each strategy was favored at willingness-to-pay values < $100,000 QALY

3.4 Discussion

The model estimated the value of the 4PPTP using two outcomes: 1. the estimation of the incremental cost effectiveness ratio and 2. the estimation of public health outcomes. The ICER represents the difference between the ratios of expected cost to expected effectiveness for the program vs. the base case and other strategies. This value is expressed in $/QALY. While it has no absolute meaning, the ICER provides a standardized unit by which health interventions can be compared. The ideal, though uncommon, result is an intervention that is both less expensive and more effective than the standard treatment. Such an intervention is said to be cost saving. An equally conclusive result is represented by dominated strategies. A strategy is said to be dominated when it is more expensive and less effective than alternative treatments. All other strategies are therefore more effective and more expensive than the standard treatment and can be ordered by ICER. Though often debated, European health agencies frequently consider interventions with a non-dominated ICER of $50,000/QALY to be good value while US agencies often use a more generous valuation of $100,000/QALY.

Estimation of public health impact, a second experimental outcome, is frequently helpful in considering population-level policy decisions. In addition to the tabulation of cost and effectiveness for each branch, the model also tracked incidence of outcomes in the study population. Multiplying this observed incidence in the No-Program arm by census estimates, results in baseline incidence of each outcome produced by standard practice. Similarly, computing incidence in the intervention arm allows for comparison of cases averted by the experimental strategy. Although interpretation of these estimates is colored by ethical considerations, the magnitude of total number of cases averted in the context of the total population does offer useful

insight into the possible scope of an intervention. Presently, there are no conventions for interpretation of these estimates.

Analysis of the outcomes data collected from the 4PPTP for immunization ABFM PPM, suggest that the program is a cost-effective intervention to increase vaccination rates in the primary care setting with clear public health benefits. Rates of vaccination increased across all measured immunizations with percentage point increases ranging from 8.1 for herpes zoster vaccine to 17.4 for pneumococcal vaccines. Using a societal perspective, the program was favored over standard practice as measured prior to the intervention and resulted in the gain of 0.0066 QALY (2.40 days) at a cost of only $4,927/QALY. When extrapolated to the population 65 years of age or older, the program would avert over 2.38 million cases of disease, 163,280 hospitalizations and 27,736 deaths over a 10-year time horizon.

Sensitivity analyses showed that the program would likely remain the favored strategy with a willingness-to-pay between $5,000 (p=.53) to $20,000 per QALY (p=.99) and was very strongly favored above $20,000 per QALY (p>.99). The most influential drivers of uncertainty in the model were related to influenza epidemiologic dynamics, which accounted for 89% of total uncertainty. Increased influenza vaccine uptake had the greatest leverage in the model. This is not surprising for two reasons. First, as an annual vaccine, over the 10-year time horizon, influenza-related effects could be replicated up to 10 times. Secondly, uptake is correlated with the opposing dynamics of vaccination costs vs the costs of disease where effectiveness is also related to broad ranges of seasonal variability in vaccine effectiveness, disease infectivity and virulence. Combined, the uncertainty of each of these dynamics and the potential cumulative frequency of annual effects leads to the least predictable behavior in the model. A similar pattern was also evident in

pneumococcal-related factors where uptake, vaccine cost, infectivity and vaccine effectiveness all interact to contribute uncertainty, albeit with a much smaller combined effect than influenza.

Limitations exist. As with all modeling analyses, parameter estimates can be imprecise and often represent dynamics which have not been directly studied. In this model, factors related to herpes zoster were extrapolated from the best available data in the absence of clinical trials in the experimental cohort. Some secondary effects such as herd immunity and susceptibility to coinfection were also excluded from the model to improve interpretability and clarity. Likewise, pneumococcal vaccination was collapsed into an assumed two-dose series to best fit the available outcomes data. It is possible that relaxing this assumption with more specific outcomes data may reduce uncertainty. Public health outcomes should be interpreted with caution. Total cases were derived from US census data; however, the experimental strategy targets primary care physicians and individuals without a primary care provider would not benefit from the program. Finally, the limited sample size using self-reported outcomes data only suggests what might be observed in a population-wide deployment of the program.

Unlike the calculation of immunization rates which is influenced by the modeling assumptions described above, VE is an uncomplicated algebraic operation. As all vaccines are thoroughly tested and monitored through clinical research trials and ongoing population surveillance, the modeling of VE is simply the likelihood of infection given vaccination. Complexity arises however, when VE is unknown in a population; for example, when a model considers a hypothetical extension of the ACIP recommendation to a new population, variations in vaccine production runs or distribution stress, or when VE is affected by another factor, such as waning immunity over time. Circumstances such as these are not modeled in this analysis.

Despite these limitations, the model proved to be robust and was tested with a wide range of potential values. The results strongly suggest that the 4 Pillars™ Practice Transformation Program for immunization is a cost-effective strategy to decrease the burden of vaccine preventable disease in the US population of older adults. Increased adoption of the program is advisable.

4.0 Implementation of the 4 Pillars™ Practice Transformation Program as a Quality Improvement Initiative

The 4PPTP was pilot tested as a quality improvement initiative in the primary care division of a large regional health system. This opportunity drove further innovation in program design as well as significant learning about the differences between the dynamics of a clinical trial and the realities of interventions executed outside of a laboratory environment. Despite positive feedback from all stakeholders, significant changes in outcome measures were not detected in the available data. The following chapter discusses the implementation of the program, summarizes outcomes and discusses potential drivers of the results. Opportunities for improvement in future efforts to increase vaccination rates through primary care practices are proposed.

4.1 Introduction

For any intervention to confer benefits to a population, the intervention must be implemented at scale. This process of translation from the research laboratory to the "real world" is challenging and outcomes may differ dramatically from what was achieved in carefully controlled conditions. While the effectiveness of many health interventions can be maximized through technical or physical processes, interventions which depend on the alteration of behavior are subject to additional sources of uncertainty that may not be easily anticipated during translation. Despite careful preparation and additional tailoring of the program, these behavioral factors may have interfered with program fidelity.

The effectiveness trial was initiated at the request of the executive leadership of a large regional health system to address a perceived opportunity to improve adult immunization rates within their patient population. After several stakeholder meetings, all decisionmakers agreed to develop a customized version of the existing 4 Pillars™ intervention and to implement the new product in phases throughout the adult primary care practices of the health system. At the conclusion of the trial, 63 practices completed the intervention to improve measures of the adult vaccinations for; seasonal influenza (Flu), pneumococcal (Pneumo) & pneumococcal conjugate (PCV), tetanus-diphtheria (Td) & tetanus-diphtheria-pertussis (Tdap), and herpes zoster (Zoster). Analysis of variance testing of the practices' before and after vaccination rates and missed opportunities to vaccinate did not reveal significant differences among the groups.

4.2 Methods

4.2.1 Implementation Methods

The implementation team drew heavily from the theoretical models presented in chapter 1.0 to translate the clinically efficacious 4PPTP to a more generalizable version. At the macro level, the process followed the Implementation Stages of exploration, installation, initial implementation, and full implementation as described in section 1.1.5.1. During this process, the existing software and deployment plan were customized through a series of stakeholder meetings, planning sessions and a pilot trial within a subset of the practices. A working group was formed and populated by both internal and external stakeholders. Internal members from the health care organization included executive leaders, members of the organization's quality, operations, and

data departments, medical directors, practice managers, nursing supervisors and practice physicians. The external implementation team included educators from a pharmaceutical company and the authors of the 4 Pillars™ program and support staff.

During the exploration stage the working group focused on knowledge transfer from each of the component teams. The organization presented their best estimates of current vaccination measures, available resources and desired outcomes from the proposed quality improvement program in vaccination. Representatives from the pharmaceutical company, shared a successful program which was implemented in a similar health care organization and committed to providing personnel to help implement the program. The 4 Pillars™ team presented the successful clinical trial outcomes and demonstrated the software and program design. The working group agreed to implement the 4PPTP throughout the organization's practices in phases; where the first phase would serve as a pilot to reveal any issues that may need to be resolved before full deployment.

In preparation for the pilot phase, the working group met as needed to identify and address potential threats to the program. All parties agreed that the engagement of practice staff would be critical and that enrollment in the program would need to be carefully scripted. The resulting three meeting enrollment protocol replicated the first three stages of implementation at the practice level. (See 1.1.5.1) This enrollment protocol began with a memorandum from the organization CEO to the practice staff as displayed in Appendix A. Subsequently, the following meetings were scheduled by an educator from the pharmaceutical company (Facilitator) with practice staff and a designated Immunization Champion (IC).

1. Practice Leadership Meeting - On site meeting with Facilitator and practice leadership during a normally scheduled monthly meeting.

a. Pre-Intervention Self-Evaluation - Independent self-evaluation of practice readiness for change and baseline data collection (see A.2)

2. Immunization Champion Coaching Meeting - On site meeting between Facilitator and Immunization Champion to review outline of the intervention and to prepare the Immunization Champion for the staff meeting
3. All Staff Kick Off Meeting - On site meeting led by office manager & Immunization Champion supported by the Facilitator to kick off the intervention.

Upon completion of the enrollment protocol, the Facilitator prepared the practice to complete iterative Plan, Do, Study, Act (PDSA) cycles of quality improvement in a coaching meeting with the Immunization Champion. The PDSA framework was selected from other similar models for its common usage in other medical quality improvement interventions and familiarity among medical professionals. The cycles were outlined as follows:

1. Monthly PLAN step
    a. IC and Facilitator review a section of the 4 Pillars™ Vaccine Administration Readiness Questionnaire, immunization data, and/or Nurse Practice Inventory.
    b. Identify strategies from the toolkit to implement during the month with documented SMART goals to bring the plan to the other office staff
    c. Schedule DO touch point within a week
    d. Schedule STUDY touch point prior to next monthly staff meeting

2. Monthly DO step
    a. IC implements SMART goals contacting facilitator as necessary
    b. IC and Facilitator review SMART goals within a week and make changes to the goals as necessary
3. Monthly STUDY step
    a. IC and Facilitator review SMART goals and successes/challenges from DO step
    b. IC and Facilitator prepare a summary of the monthly DO activities and immunization trends from data
    c. IC and Facilitator prepare a recommendation for office system enhancements based on learning
4. Monthly ACT step - IC presents recommendations to office leadership
    a. IC presents summary, data, and approved recommendations at the next staff meeting

This schedule conforms to the Diffusion of Innovations model by staging communication with practice staff over time. Early adopters could emerge as the practice moves through the enrollment while the majority would be exposed to training during repeated PDSA cycles. In this way, all team members would be allowed to adopt new behaviors at a comfortable pace. Similarly, the role-centered meetings were designed to build and strengthen the *integrated and compensatory implementation drivers* of; 1. Competency, 2. Organization and 3. Leadership discussed in 1.1.5.2. Sample agendas for the meetings are presented in Appendix B.

The first practice was enrolled in the spring of 2015 and was followed by 62 other practices as shown in Table 10. The program was terminated in the summer of 2017 in response to shifting strategic objectives of the program's stakeholders.

Table 10 Enrollment schedule

Phase	Intervention start	Location count
1.0	2015-04-08	14
2.0	2016-02-28	13
3.0	2015-08-16	21
4.0	2016-10-19	13
5.0	2017-05-06	2

4.2.2 Analytic Methods

The effectiveness of the intervention was evaluated using improvements in vaccination rates and reductions in missed opportunities to vaccinate. These outcomes were calculated, from data files pulled from the health organization's electronic medical records (EMR). Patient-level data was aggregated to practices and outcomes were computed. Outcomes were evaluated using an analysis of variance procedure and were considered significant when the alpha level of the F statistic was greater than 0.05 and the change in before/after measurements occurred in the expected direction. Source code for all data processing steps and analyses is available at https://github.com/PittVax/4Pillars_Outcomes including documentation of all software packages and versions used.

An analyst from the organization generated the data files by searching for patients 60 years of age or older who visited any of the practices in the intervention list during the baseline (4/1/2014 – 3/30/2015) or follow-up (4/1/17-3/30/2018) periods and then retrieving attributes from those patient's records. Each patient was uniquely identified by a record number generated by the organization's de-identification procedure. Birth date was the only demographic information provided.

The available data, which came aggregated to the time period and Location, was parsed and carefully examined for anomalies using descriptive statistics and plots then organized into 'tidy' format indexed by Patient ID, Timepoint, Location ID, and Department. Locations could include multiple Departments. For example, a location may include Dr. Smith's East Office, Dr. Smith's West Office and Dr. Smith's Walk-in-clinics at both offices. Columns included the feature values for each uniquely indexed row as follows:

- the date of the first visit the patient had to any department within the Location during the time period,
- the date of the first visit the patient had to any department within the Location during the flu season (August-April) of the time period,
- the total number of encounters to any Department(s) of the Location during the time period,
- the total number of encounters to any Department(s) of the Location during the flu season (August-April) of the time period,
- the date of the last vaccine administration and
- an indicator if a vaccine was administered at a visit during the time period.

The age-appropriate vaccines recommended to the population during the study were: influenza, Pneumo, PCV, Td, Tdap and Zoster. Adult vaccination schedules were unchanged throughout the baseline, intervention and follow-up periods; therefore vaccine eligibility was calculated identically for each time period using the following recommendations: (See compute_vaccine_logic())

- Pneumo & PCV should be administered to all patients 65 years or older.
- Influenza vaccine should be administered to all patients every year.
- Zoster & Tdap vaccines should be administered to all patients.
- TD should be administered every 10 years to all patients and can be replaced once by a dose of Tdap.

Indicator variables for vaccine eligibility were added to the data for unvaccinated patients meeting the recommendation criteria. Similarly, indicator variables for vaccine administrations were tallied from eligible individuals who were vaccinated at a visit or elsewhere during the time period.

These patient-level features were then aggregated to the most granular practice level possible – Location. This limitation in the data produced an assumption that all departments within a location would have been comparable. Interviews with practice staff and the implementation team, suggested that multiple primary care departments within a location would likely be similar, however “walk-in clinic” departments may have been qualitatively different than primary care departments.

Figure 11and Figure 12 show two possible Location configurations. For example, one could assume that Dr. Li’s East office and Dr. Li’s West office would likely serve similar patient populations and have similar staff who would have conducted the intervention in a similar way.

However, if Dr. Ismael's Location included her North office and her walk-in clinic, those departments may have had important differences.

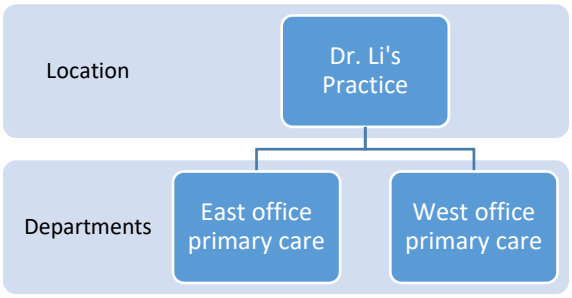

Figure 11 Hypothetical location showing a practice with two primary care offices and no walk-in-clinics

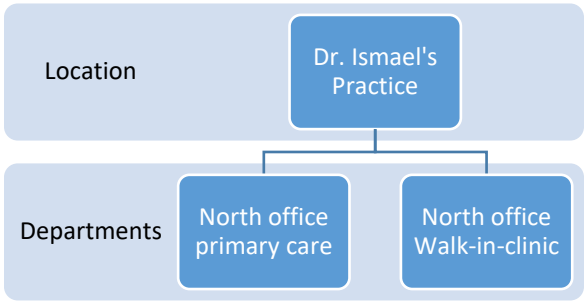

Figure 12 Hypothetical location showing a practice with one primary care office and one walk-in-clinic in the same building

Additionally, during the intervention period, the organization underwent a significant restructuring where some Locations were closed, consolidated or moved in response to changing business conditions in primary care. Consequently, not all Locations had the same departments in both the before and after data. To minimize potential confounders, the aggregated data was compared by time point and by Location and any anomalous records were either excluded, updated or analyzed as described below.

The function questionable_departments() was used to examine records and adjustments were made with update_site_names() and drop_site_records(). Records associated with eight different departments changed department ID. Their records were examined with descriptive statistics and plots and appeared to be similar to data from other locations. These records were recoded so that the Locations could be compared across the time points. Five departments were excluded due to missing data from either the baseline or follow-up files. Twelve departments who were not enrolled in the intervention were excluded. These records were likely an artifact produced by the query used to retrieve the visits associated with specific patients. Excluding these records would have no effect on the analysis. Similarly, six "care management" departments were also excluded as visits assigned to those codes, would not be expected to assess immunization status nor to have the opportunity to administer a vaccine. Finally, three strategies were developed and tested to account for Locations which included a walk-in clinic.

Due to the structure of the available data, excluding visits to the walk-in-clinics could bias results for the location. From a provider perspective, walk-in-clinic appointments are focused more on emergent conditions and less on preventive care. Though vaccination is rarely contra-indicated by the typical conditions addressed in walk-in-clinics, vaccine assessment may be overshadowed by more urgent complaints. Similarly, from a patient perspective, vaccination at a walk-in-clinic visit may be perceived as too burdensome to consider while injured or ill. Likelihood of vaccination may also vary from other departments as not all patients seen in a location's walk-in-clinic are necessarily primary care patients at the location. That is, patients whose primary care provider practices at the location often seek urgent treatment at the location's walk-in-clinic, but the reverse may not be true. Three strategies were developed to test the sensitivity of visits coded to the walk-in-clinic departments.

- Strategy 1 (Filter) included patients seen in the Locations' walk-in-clinics in the aggregated location counts. This included visits where assessment of vaccination may differ from its priority during a scheduled visit. Consequently, if a large proportion of walk-in patients did not also visit the location for preventive services the location may have shown more missed opportunities.
- Strategy 2 (Exclude) excluded patients seen in walk-in-clinics from location visit counts. This eliminated the count of visits from patients whose medical home resides elsewhere but penalizes sites who do prioritize vaccination at walk-in clinic appointments. For example, locations who code drop-in vaccination clinics as walk-in visits or whose clinical staff do use urgent care visits as an opportunity to vaccinate, will not be credited for these efforts.
- Strategy 3 (Drop) excluded all locations with more than a 5% difference between patient counts produced by strategy 1 and strategy 2.

Finally, outcomes were calculated for each Location, vaccine, and time point. The vaccination rate was computed as the number of immunized patients divided by the number of unique patients. Vaccinations administered during a visit as well as those administered elsewhere, were included in these counts. The missed opportunity rate for each vaccine was calculated as the ratio of visits by patients eligible and unvaccinated to the total number of visits to the location during the time period.

An analysis of variance (ANOVA) procedure was conducted using the Location-level aggregated data for each vaccine for both vaccination rate and missed opportunities. Vaccination

outcomes by vaccine were considered significant if the magnitude of the difference between baseline and follow-up measurements occurred in the expected direction (increase for vaccination rate, decrease for missed opportunities) and if the probability of observing the calculated F statistic was <0.05.

4.3 Results

4.3.1 Patient descriptors

As shown in Table 11 and Table 12, 70,503 patients 60 years of age or older, visited an intervention location during baseline (19,359 < age 65) and 81,078 during follow-up (21,736 < age 65). The intervention was conducted over approximately two years through four major phases and one final phase for all remaining location. Assuming that the patient population during the intervention was similar to the baseline measurements, each major phase impacted approximately 15,000 patients and included approximately 15 sites. Proportions of patient ages were similarly distributed throughout the phases. Mean number of patients per location was 1,763 (std=1,142).

Table 11 Patient totals by age and time period

	60-64	**65+**	**Total**
Baseline	19,359	51,144	70,503
Follow-up	21,736	59,342	81,078
Total	41,095	110,486	151,581

Table 12 Patient totals by age and phase of intervention

	60-64 years	65+ years	Total	Intervention start	Location count
1	4,970	13,101	18,071	4/8/2015	14
2	4,601	11,851	16,452	2/28/2016	13
3	5,577	14,139	19,716	8/16/2015	21
4	3,398	10,122	13,520	10/19/2016	13
5	813	1,931	2,744	5/6/2017	2
Total	19,359	51,144	70,503		

4.3.2 Adjustments for Locations with a Walk-In-Clinic

Between the baseline and follow-up data pulls, locations and departments were reorganized and many locations added a walk-in-clinic department. Three strategies of modeling the potential impact were compared by visually inspecting violin plots and by comparing the results of ANOVA analyses using each of the three data sets. There were no substantial differences among the plots or statistical tests of the strategies.

Seven locations were affected by the addition of a walk-in-clinic department. Comparing the patient counts produced by the alternative strategies resulted in a five percent difference in four locations as shown in Table 13. However, the results of the hypothesis test did not change across the three variations of the data.

Table 13 Comparison of patient counts using different strategies for walk-in-clinic visits

Site ID	Patient count with WIC (Strategy 1)	Patient count without WIC (Strategy 2)	Percent Difference	> 5% Difference
4	3,016	2,917	1.67%	
6	1,693	1,602	2.76%	
2	3,595	3,390	2.93%	
0	6,950	6,363	4.41%	
7	3,449	3,069	5.83%	*
1	2,103	1,362	21.39%	*
5	3,091	1,789	26.68%	*
3	3,247	1,555	35.24%	*

Figure 13 through Figure 17 show the similarities among the strategies. Like box and whisker plots, violin plots include the most extreme values at either end of the diagram. They also convey the shape of the distribution of results through the width and shape of the violin body and neck. For example, influenza vaccination rates during baseline appear to be normally distributed around 0.55 with some outliers toward 0.30, whereas PCV vaccination rates during baseline are asymmetrically skewed towards 0.10.

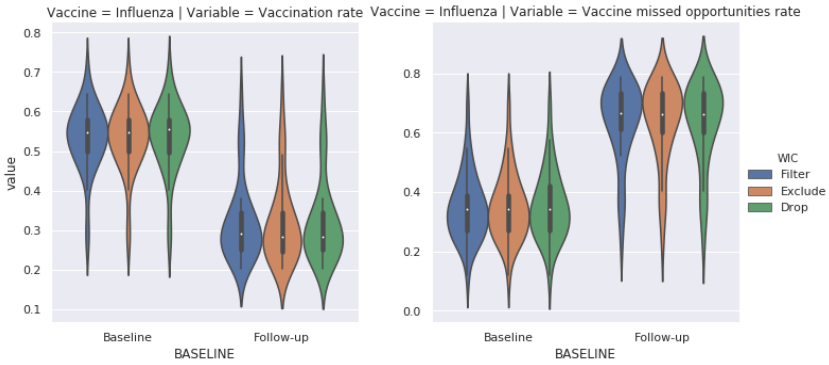

Figure 13 Walk-in-clinic strategy comparison for influenza outcomes

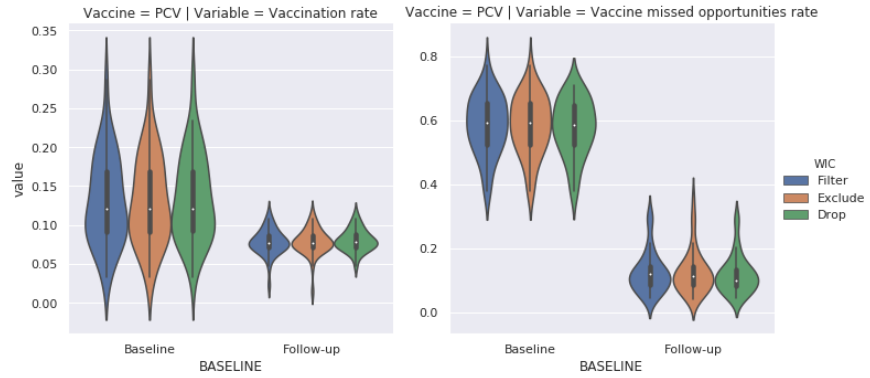

Figure 14 Walk-in-clinic strategy comparison for PCV outcomes

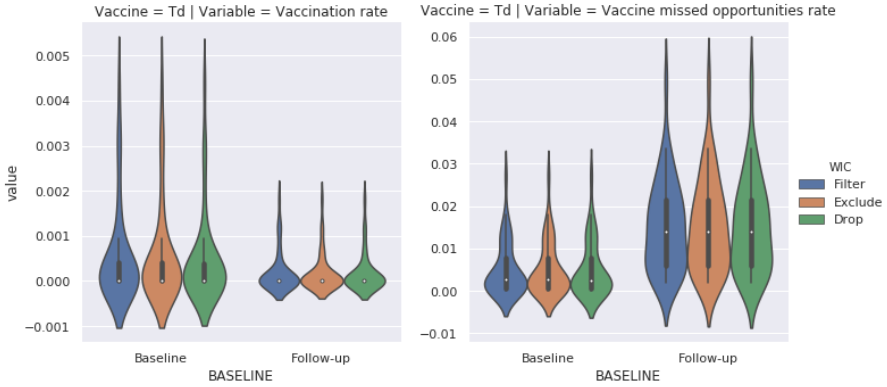

Figure 15 Walk-in-clinic strategy comparison for TD outcomes

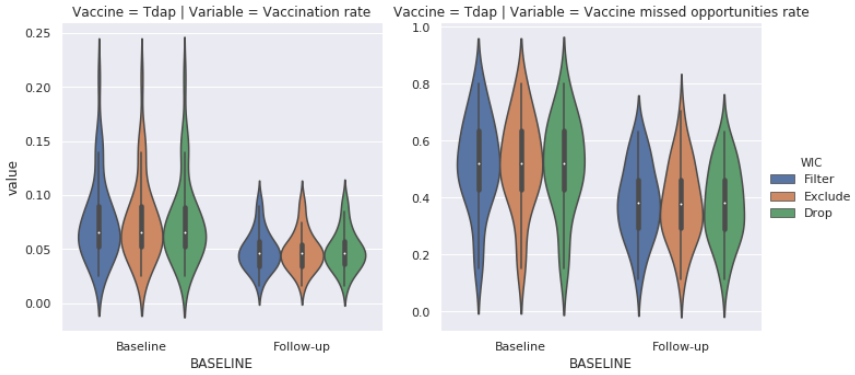

Figure 16 Walk-in-clinic strategy comparison for Tdap outcomes

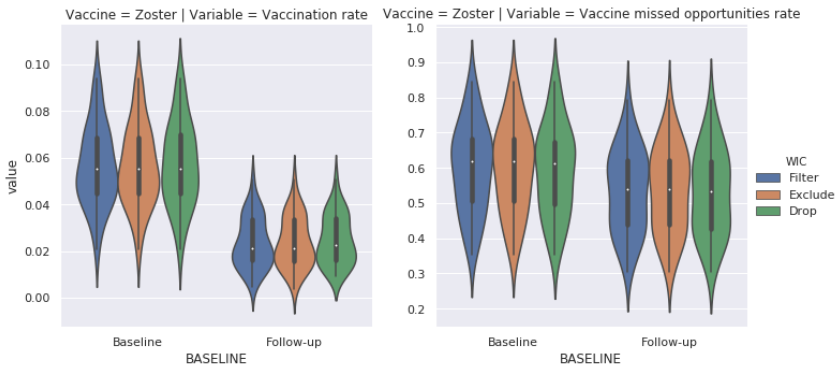

Figure 17 Walk-in-clinic strategy comparison for Zoster outcomes

After performing these sensitivity tests, Strategy 2 (Exclude) was selected as the most representative model of clinical behavior. This excludes patients seen in walk-in-clinics from location visit counts.

4.3.3 Outcomes

Complete tables of aggregated outcomes are reported in Appendix C. Summaries are shown in Table 14 and Table 15. During the baseline period, 70,503 patients logged 246,921 total visits to any location with mean patients per location of 1,762.58 (sd=1,142.25) and mean visits per location of 6,173.02 (sd=4,309.30). Of those visits, 164,971 occurred during flu vaccination season with mean visits per location of 4,124.27 (sd=2923.96). During the follow-up period 81,078 patients logged 282,279 total visits to any location with mean patients per location of 2,026.95 (sd=1,271.17) and mean visits per location of 7,056.98 (sd=4,695.81). Of those visits, 191,584 occurred during flu vaccination season with mean visits per location of 4,789.60 (sd=3,266.89).

The average number of patients per location who were eligible for each vaccine according to CDC recommendations is reported in the column “Vaccine eligible.” At baseline, the vaccines with the highest average eligibility were influenza (mean 1395.95, sd 910.70) and PCV (mean

1,260.50, sd 823.65). The vaccines with lowest average eligibility were Pneumo (mean 433.65, sd 320.74) and Td (mean 8.43, sd 10.67). The vaccines for Tdap (mean 1,078.85, sd 722.84) and Zoster (mean 1,168.12, sd 769.57) were in the middle of the range of average patients eligible per location. The rank order of average eligibility per location was different at Follow up. Influenza remained the highest (mean 1,625.72, sd 1,053.50) and Td remained the lowest (mean 30.52, sd 30.06). The average number of patients per location eligible for Zoster (mean 1,176.00, sd 789.11) remained largely unchanged, while PCV (mean 430.45, sd 330.24) and Tdap (mean 900.77, sd 623.61) both fell and Pneumo (mean 531.45, sd 381.56) rose slightly.

The average baseline vs follow-up vaccination rates of eligible patients by location were computed as: influenza 53.39% vs 31.69%, PCV 13.10% vs 7.83%, Pneumo 6.74% vs 6.85%, Td 0.06% vs 0.02%, Tdap 7.55% vs 4.84% and Zoster5.62% vs 2.36%. The average numbers of vaccines administered during an eligible patient's visit mirrored the number of eligible patients during baseline but not during follow-up. Also, Zoster was rarely administered during a visit during either time period despite the large number of eligible patients.

An analysis of variance procedure was used to identify significant changes in vaccination rates and missed opportunities to vaccinate. Results are summarized in Table 16. All outcomes except those associated with Pneumo vaccine were significant, however only the reductions in missed opportunities to vaccinate with PCV (45.88 percentage point reduction), Tdap (13.39 percentage point reduction) and Zoster(6.43 percentage point reduction) vaccines were both significant at $p<0.05$ and in the expected direction. All vaccination rates except for Pneumo (0.0011 rate increase) were lower during follow-up than during baseline. Influenza rate decreased by 0.217, PCV by 0.0527, Td by 0.0004, Tdap by 0.0271 and Zoster by 0.0326. Missed

opportunities to vaccinate increased for influenza by 0.2886, Pneumo by 0.0059, and for Td by 0.01, and decreased for PCV by 0.4588, Tdap by 0.1339 and Zoster by 0.0643.

Table 14 Summary of vaccination rates by location by vaccine

		Patients		Vaccine eligible		Immunized		Vaccination rate	
		mean	sd	mean	sd	mean	sd	mean	sd
Baseline	Flu	1,762.58	1,142.25	1,395.95	910.70	944.98	648.66	0.5339	0.0834
	PCV	1,762.58	1,142.25	1,260.50	823.65	236.53	190.13	0.1310	0.0569
	Pneumo	1,762.58	1,142.25	433.65	320.74	117.65	91.99	0.0674	0.0240
	Td	1,762.58	1,142.25	8.43	10.67	0.82	1.32	0.0006	0.0011
	Tdap	1,762.58	1,142.25	1,078.85	722.84	140.30	137.23	0.0755	0.0381
	Zoster	1,762.58	1,142.25	1,168.12	769.57	95.40	67.97	0.0562	0.0169
Follow-up	Flu	2,026.95	1,271.17	1,625.72	1,053.50	625.05	466.09	0.3169	0.1038
	PCV	2,026.95	1,271.17	430.45	330.24	155.00	93.93	0.0783	0.0170
	Pneumo	2,026.95	1,271.17	531.45	381.56	138.10	95.16	0.0685	0.0204
	Td	2,026.95	1,271.17	30.52	30.06	0.25	0.49	0.0002	0.0004
	Tdap	2,026.95	1,271.17	900.77	623.61	93.08	59.41	0.0484	0.0180
	Zoster	2,026.95	1,271.17	1,176.00	789.11	45.23	35.29	0.0236	0.0108

Table 15 Summary of missed opportunities rates by location by vaccine

		Visits during time period		Vaccine administered at a visit		Vaccine missed opportunities rate	
		mean	sd	mean	sd	mean	sd
Baseline	Flu	4,124.27	2,923.96	823.05	569.44	0.3476	0.1112
	PCV	6,173.02	4,309.30	218.82	181.48	0.5843	0.0917
	Pneumo	6,173.02	4,309.30	104.40	83.42	0.1824	0.0743
	Td	6,173.02	4,309.30	0.33	0.86	0.0051	0.0063
	Tdap	6,173.02	4,309.30	124.83	127.82	0.5170	0.1642
	Zoster	6,173.02	4,309.30	54.40	49.14	0.6006	0.1248
Follow-up	Flu	4,789.60	3,266.89	509.20	404.41	0.6362	0.1363
	PCV	7,056.98	4,695.81	142.30	87.74	0.1255	0.0678
	Pneumo	7,056.98	4,695.81	126.70	90.07	0.1883	0.0643
	Td	7,056.98	4,695.81	0.05	0.22	0.0151	0.0108
	Tdap	7,056.98	4,695.81	73.85	48.59	0.3831	0.1370
	Zoster	7,056.98	4,695.81	29.20	27.07	0.5363	0.1195

Table 16 Analysis of variance results for vaccination outcomes compared before and after intervention

		Baseline	Follow-up	Sum sq	Df	F	PR(>F)	Significant < 0.05	Significant < 0.05 in expected direction
Vaccination rate	**Influenza**	0.5339	0.3169	0.9418	1	106.2324	0	*	
	PCV	0.131	0.0783	0.0556	1	31.5145	0	*	
	Pneumo	0.0674	0.0685	0	1	0.047	0.8289		
	Td	0.0006	0.0002	0	1	4.3564	0.0401	*	
	Tdap	0.0755	0.0484	0.0147	1	16.5492	0.0001	*	
	Zoster	0.0562	0.0236	0.0212	1	105.3741	0	*	
Vaccine missed opportunities rate	**Influenza**	0.3476	0.6362	1.6659	1	107.6812	0	*	
	PCV	0.5843	0.1255	4.2085	1	647.3124	0	*	*
	Pneumo	0.1824	0.1883	0.0007	1	0.1455	0.7039		
	Td	0.0051	0.0151	0.002	1	26.0067	0	*	
	Tdap	0.517	0.3831	0.3589	1	15.7038	0.0002	*	*
	Zoster	0.6006	0.5363	0.0824	1	5.5223	0.0213	*	*

4.4 Discussion

The reduction of missed opportunities to vaccinate with PCV, Tdap and Zoster vaccines was statistically significant, however the effectiveness of the intervention remains unclear. Secular trends may have confounded the observed results. Data availability and methodologic limitations prevented the use of more sophisticated analytic tools. Future intervention efforts should prioritize real-time data availability and tighter integration into existing business operations and workflows.

The intervention design was a novel use of available resources but was likely less intensive than what was provided in prior implementations. Utilizing an educator from industry minimized implementation costs but limited the amount of support available to immunization champions at each location. Also, using a consultant external to the organization may have reduced the perceived importance of the intervention to front-line staff as well as minimized organizational commitment to the project. This dynamic was also observed in prior trials where the consultant was part of the research team and external to the organization. Future iterations of the program should consider using an individual such as an educator or quality assurance team member from within the organization as the program facilitator.

Data availability was another limitation. The organization did not have a clear understanding of vaccination outcomes prior to, or during the intervention. The EMR used in the organization did not offer the ability to report aggregated measures, so the program participants could not automate the motivational strategies from Pillar 4 and did not have the capacity to manually track progress. Additionally, the available data may have underreported intervention outcomes. With the increase in community vaccination locations such as pharmacies and without

mandatory reporting pipelines, it is possible that non-clinical administrations may not be consistently entered into the EMR. Because the follow-up data was drawn at differing intervals from program completion, performance during and immediately after the intervention may have systematically differed from the performance captured in the available data. Though untested, it is possible that the observed declines in outcomes were less severe than would have occurred without the program, but such an analysis was impossible with the provided data. Future versions of the program should not only collect data more proximal to the program, but also return real-time progress reports to participants to enhance motivation.

Finally, the organizational landscape changed dramatically during the intervention period. Nationally, insurers, providers and other stakeholders in the health care industry all wrestled with policy changes and the shifting paradigm of primary care under the Affordable Care Act as evidenced locally by the organization-wide restructuring of departments and business entities. Program participants may have been too overwhelmed by disruptions to established routines to attend to the quality improvement program. Similarly, research staff have observed firsthand, that the EMR has become the primary interface between standards of care and clinical providers. Asking providers to switch contexts to an external resource such as a website or to physical job aids is a barrier to program fidelity. Consequently, interventions which rely on staff behavior change, should be tightly integrated into a stable clinical environment so that a minimum number of changes are expected from personnel.

Despite the ambiguous quantitative results, it is likely that the implementation of the 4 Pillars™ Practice Transformation Program for Immunization was more beneficial than detrimental to the organization and patient population. However, the collaborative design of the intervention strategy, limitations in data availability and substantial environmental disruption during the

intervention period prevented the replication of results observed in previous clinical trials using the program. Future implementations of this and similar programs should prioritize mitigation of these issues to achieve maximum impact.

5.0 Summary and Conclusions

Stanley Kubrick and Arthur C. Clarke's science fiction masterpiece *2001: A Space Odyssey* (113) chronicles a surprisingly plausible epic that begins with and culminates in the next genesis of humankind. Kubrick and Clarke cinematically assert that evolutionary inflection points occur with the discovery of new technologies that extend the capabilities of individuals and societies which leads to a virtuous cycle of health improvement and morphologic evolution. While their vision of 2001 was premature, the storyline is surprisingly plausible. In the fifty years since the release of the film, human technologists and explorers have visited the moon, commercialized spaceflight and have built primitive artificial intelligence software that may soon control the on-board systems of our most common terrestrial vehicles.

As suggested in the iconic sequence of primitive man's discovery of tools, dramatic technological innovations have been enabled by the improvement of humanity's physical conditions. Now motivated by an exponentially growing world population, scientists and engineers continue to boost resource production and to learn how to prevent and how to treat the greatest threats to life. The traumatic conflict aboard *Discovery One* between mankind's hero Dr. David Bowman and the personification of technology, HAL-9000, portrays the often-hostile interface between scientific advancements and naive humans adapting to new capabilities. Though dystopic, it is at this nexus that the greatest evolutionary moments can occur.

Medical practice and population healthcare embody one of these hostile environments where the atomic elements of human beings, scientific innovations and resources collide in an ongoing nuclear reaction. When the chain reaction is carefully managed, such as was the case with polio eradication, great triumphs are achieved. When the chain reaction becomes unbalanced, it

can result in great detriment as was the case with over-prescription of pain relievers and the ongoing opioid epidemic. This volatile and highly energetic environment is complex and dynamic. It requires safeguards, feedback systems and catalysts analogous to control rods that can govern the speed of the reaction. Unfortunately, modern epidemiologists are as far from a real-time understanding of the state of population health as 2019 moviegoers are from Kubrick and Clarke's future in 2001. Steps are being taken towards a more flexible health delivery system, however, as the same principles of continuous quality improvement championed by the Toyota Method have infiltrated the health delivery system.

5.1 Lessons for Future Implementations of Public Health Interventions Deployed Through Primary Care Practices

In today's healthcare environment where payors demand efficiency, consumers demand convenience and regulators demand quality, medical providers and health administrators are struggling to satisfy the expanding needs of all stakeholders. These demanding conditions coupled with the relentless advance of treatments, technologies and standards of care challenge the sanity of even the most phlegmatic healthcare personnel. Yet, difficulty is no excuse for apathy.

To codify goals for the health delivery network, standards such as the Medicare Star program have been institutionalized for insurers. With strong incentives for compliance, insurers are passing relevant expectations on to providers. While setting goals is necessary, goals alone are insufficient to achieve changes to long intrenched patterns of behavior. Therefore, quality improvement programs such as the 4 Pillars™ Practice Transformation Program for Immunization

seek to routinize the path from current behavior to new behaviors better aligned with quality standards.

This transition has proven to be extraordinarily difficult. Even some of the most obvious and seemingly simple behaviors take considerable effort to manipulate. Handwashing, for example, is an undisputed necessity in modern health care and yet still requires ongoing focus to prevent transmission of infections in clinical treatment facilities. As complexity of systems increases, so do the challenge to altering that system. Through this struggle, knowledge gaps have been filled by the maturing fields of implementation science and quality improvement. Using these frameworks, carefully executed clinical trials have demonstrated that clinicians can achieve improvements in patient outcomes, but efficiently generalizing this effect to the greater primary care health delivery system has yet to be demonstrated reliably in most domains.

The testing, development and implementation of the 4PPTP have revealed several barriers to effective translation and scalability of the program. As is the case with many public health initiatives, problems which were addressed by the program at the individual and interpersonal level of the social ecological hierarchy are mirrored in the higher, encapsulating levels. Not surprisingly, these barriers can be categorized into the same 4 Pillars™ which proved necessary to achieve behavior change at the provider and practice level. Moreover, these barriers are likely common across many domains of practice so focusing on the solutions to systemic problems should be fruitful for outcomes beyond the specific case of vaccination addressed in this project.

5.1.1.1 Convenience

Quality improvement interventions must be as simple and time efficient as possible. Staff are already burdened with extraordinary responsibility and any changes to routine or the addition of new processes represent a cognitive load that is often deferred indefinitely or worse, minimally

and incorrectly implemented. It is easy for scientists who may spend years studying a single problem, to try to provide as many solutions as possible to affect a change in a clinical outcome. However, this shotgun approach is likely to overwhelm staff and to meet organizational resistance.

At the individual and group level, any intervention strategies that are not virtually transparent to staff should be carefully considered and eliminated if possible. If any element of the program requires a conscious behavior change, the element should be a necessity to achieving the outcome. If a similar outcome can be achieved through the manipulation of any other leverage point in the system, that alternate strategy should be selected. Strategies that do require the cooperation of team members must be scripted, tested and packaged to gain adoption with the least amount of individual effort possible. Support for the behavior change should cascade from the most distal inputs through every concentric level of the system surrounding the desired behavior. A perfect application of these principles of convenience would make it more difficult for actors to avoid the behavior than to execute the behavior.

Stakeholders at the organizational and institutional level, must be committed to shouldering the burden of convenience on behalf of front-line individuals. Implementing a quality improvement program requires that administrators, directors, trainers and managers support front-line staff to achieve the organizational goal. If customization and development of program elements is required, those tasks should be completed prior to deploying the program globally with representatives from the front-line staff. If an organization is not willing or able to devote supportive resources to the effort, implementing the program should be deferred. Considering the organization's placement along the Stages of Change continuum may be helpful to evaluate readiness.

Intervention consultants and scientists bear the most responsibility for engineering convenience. It is not enough to test the components of the intervention. The deployment of the intervention must also be tested across a sample of representative organizations. Just as front-line staff are overwhelmed with normal duties, so too are non-clinical staff. Organizational effort to adopt program elements should be calculated in advance and integrated into whatever workflows are necessary to ensure that the element is prepared for system-wide deployment.

5.1.1.2 Communication

Change is known to be difficult for organizations and individuals alike. Open communication can help to resolve or prevent many problems during program deployment. Organizations and teams who cannot demonstrate effective channels of communication, should not consider implementing a quality improvement program before remediating this dynamic. Clear bi-directional pathways for instructions and feedback must exist or the effort will likely fail. Additionally, the organizational culture must include a tolerance for acceptable failures and have the capacity to work through setbacks.

Presenting new policies, procedures and expectations is difficult enough without having to also build training and communication systems at the same time. Implementing a quality improvement program requires specialized communication tools that may not yet exist within an organization. It is likely that an organization will minimally need tools to address staff training, compliance monitoring, outcome reporting and coaching. It is helpful, if these tools are commonly used throughout the organization and not unique to any one group of individuals. While many entities such as accreditation boards, educational institutions and special interest groups offer excellent solutions to these needs, they are typically focused on only one individual or one type of individual; for example, physicians seeking continuing medical education. This narrow focus is

prohibitive of organizational adoption. Additionally, external tools are unlikely to offer an acceptable level of convenience unless they are used as a part of a more comprehensive solution.

Finally, communication should be planned as a part of the program deployment. It is typical for a new initiative to receive much attention only to be forgotten a few weeks later. Quality improvement programs must be discussed periodically to remain salient. Similarly, overcommunication can also extinguish interest by becoming part of background corporate noise. Scientists and organizational leaders should specify a communication plan that is likely to balance the two extremes. Members of the implementation team can quickly check for salience by asking participants about the program and may be surprised to find how few team members know about the current quality improvement program and goals.

5.1.1.3 Enhanced Organizational Systems

This pillar is the most important and the most resource intensive as it is the foundation for all program components. By definition, the organizational deployment of any initiative requires enhanced systems, otherwise there would not be a need for a quality improvement program. While clinicians' individual judgements and decision making are an important part of medical care, they cannot be expected to simply make improvements in patient care without organizational support, resources and modifications to existing systems. Quality improvement must be viewed as a team sport where every member of the organization contributes to some part of the effort.

Though the practice of primary care is changing to a more centralized model, the tension between clinician autonomy and institutional standardization will remain a challenge and will necessitate careful management during implementation. For example, program components must be standardized, packaged and convenient but still allow latitude for customizations where appropriate. Options should be limited to prevent overwhelming participants, but not so restrictive

as to discourage participation. Similarly, systems that are too prescriptive and rigid cannot be used for alternative quality improvement programs. In this case, organizations can become cluttered with single use tools that cannot be repurposed. During intervention customization, organizations should be observant of systemic bottlenecks that can be adjusted to alleviate multiple quality endpoints as it is likely that any specific shortcoming is indicative of more systemic problems.

Where possible, interventions should interface with existing tools and workflows. Unfortunately, this is a significant barrier to progress in quality improvement and will remain so indefinitely. From the scientist and intervention designer perspective, limited resources prevent the development of unique integrations into every organization. From the organization's perspective, adopting new systems and tools is expensive. From the clinician's perspective, anything beyond the EMR window and perhaps email simply doesn't exist. Consequently, delivering the suite of tools required to effectively deploy any quality improvement intervention at scale will remain impossible until these dynamics shift.

5.1.1.4 Motivation

The ultimate goal of every quality improvement program should be to institutionalize and automate systems and to routinize behaviors so that quality outcomes occur independently of individual willpower. Maintaining reliance on motivation in the long-term is a poor plan for sustainability. Eventually, people get fatigued, new programs become more important and novelty wears off. Motivation is useful to defer this inevitable collapse of attention for as long as is necessary to generate new routines.

Notwithstanding the encouragement above to automate as much as possible, one especially important insight gathered from prior experience is that participation is a critical part of motivation. Most people learn best through active participation in the learning process. The need to standardize

processes and procedures needs to be balanced against the human desire to engage with new concepts and to work through new challenges. Consequently, effective coaching is an indispensable tool during program implementation. Often coaching a participant through a challenge will be substantially more motivating than trite awards and platitudes which can sometimes produce unintended negative consequences.

The most significant barrier to effective motivation encountered during this project was a lack of real-time data. In general, individuals in healthcare are caring, compassionate and self-motivated. When presented with an accurate progress report, most participants will dig in and start generating new ways to better their team's score. However, in the absence of periodic updates, staff lose interest and can then become defensive and adversarial when reports are finally produced after the intervention has concluded. Special care should be taken to provide interim feedback about progress towards outcomes so that course corrections can be made before a final outcome is calculated.

5.2 A Final Note About Data and Public Health

Quality improvement programs are driven by data, yet most personnel in a typical health care organization have very little insight into the copious data collected throughout their organization. It should be possible for any interested clinician to quickly view both aggregated and individual-level statistics for key health outcomes of their patient panel. For example, a clinician should be able to check their practice's performance on any Healthy People goal as easily as checking the schedule. Custom reports should be easy to build and accurate.

While primary care staff spend an inordinate amount of every encounter performing data entry into the EMR, this database is only one of many disparate systems that should be sharing information. Primary care physicians have been charged with the responsibility of serving as the caretaker of each patient's medical home, but do not have access to all the information necessary to coordinate care. Prescription history is stored in multiple pharmacy databases, vaccinations may or may not make it into a state registry, while the records of exercise and heart rate collected by watches, bracelets, and dongles and are managed by proprietary services. One has to think that bringing this information together would be clinically useful. However, even if the technical challenges could be overcome and every bit of health information could be aggregated into a single system, the corpus would remain worthless without more sophisticated health modeling and simulation capabilities.

Routine medical services and standards of care are established through rigorous trials, clinical experience and epidemiologic study, yet mechanics have more accessible and thorough guidance about automotive service schedules and recalls than clinicians have about their patients at the point of care. EMR vendors have attempted to solve this disparity with pop-up reminders, check boxes, screens of raw data and boilerplate notes populated from a right click menus, but most clinicians complain that these endless displays are cumbersome, difficult to navigate and a substantial distraction from the human interaction between provider and patient during a clinical consultation. Fortunately, software developers, data scientists, industrial designers and multiple specialties of engineers are working to solve comparable problems in other domains. These solutions from other industries need to be adapted to healthcare.

Meteorologists have instant access to a global network of sensors, sophisticated weather models, data sets and visualization standards that allow any knowledgeable weatherperson to

generate a local forecast on command. Automotive engineers can build a virtual engine and simulate performance characteristics from their desk. Rocket scientists can experiment with the effect of different materials on aerodynamics without needing a wind tunnel, yet physicians don't even have a complete record of their patients' medications and clinical history. This project revealed how common it is to simply accept this reality. Clinicians are resigned to spending more time interacting with computers than patients and perceive this effort as malpractice insurance rather than scientific data collection.

Future health technologists must change this paradigm and apply the same methods to healthcare that have become commonplace in other fields. The human body is complex, but we understand a great deal about how it operates and should be able to generate models and simulations that operationalize all our accumulated knowledge of this biologic machine. No single physician could ever digest and synthesize all the information that is available about each patient, but computers can do so in microseconds.

Appendix A Practice Enrollment Materials

A.1 First Contact Memo

TO: Practice Staff

FROM: Organization CEO

Congratulations! Your practice has been selected to be in the pilot phase of an improvement project to increase your vaccination rates within your practice. With our leadership and commitment to increase adult immunization rates in your practice, you will make a significant difference in patients' lives. Your contributions will impact office processes and procedures in areas of Patient Access, Patient Notification, Systems Enhancements, and Motivation.

You will be working with a facilitator from [pharmaceutical company] who will educate and provide resources to your practice in the implementation of strategies from the 4 Pillars™ Immunization Toolkit. Your colleagues and developers of the Toolkit, Drs. Rick Zimmerman & Don Middleton, along with researchers from the Pittsburgh Vaccination Research Group will also work with you through this quality improvement initiative. Protocols are being developed to enhance the team concept so our staff can assist you and other healthcare workers in closing gaps in immunization coverage.

The goal of the Primary Care Immunization Initiative is to support increasing immunization rates in adults. Incorporating adult immunization into the process of vital signs will improve the quality of life for our patients and the community in general. The intention of this group is to educate and reinforce the role of the healthcare worker to accomplish this task in the physician office.

We will need your help to:

- Identify an "Immunization Champion" (a clinical staff member within your practice) who will be supported by the [pharmaceutical company] facilitator and have access to the 4 Pillars™ Immunization Toolkit website
- Provide leadership and motivation within your practice that will allow the program to grow and spread

Our [pharmaceutical company] partners will assist you with the following:

- Get your Immunization Champion registered and provide resources for the 4 Pillars™ Immunization Toolkit website so progress of staff education, training, and competencies can be tracked
- Educate and support the Immunization Champion to be the leader in promoting and implementing 4 Pillars™ Immunization Toolkit strategies in your office
- Learn to communicate with and educate patients about the importance of immunization
- Provide feedback to clinical staff in the form of immunization rates
- Provide resources to help increase your practice's immunization rates!
- Thank you in advance for your willingness and support to educate and reinforce the role of the healthcare worker in improving patient health through patient centered, quality and safety initiatives.

[pharmaceutical company] Personnel:

[pharmaceutical company] Vaccine Facilitator:

[pharmaceutical company] Vaccine Facilitator: [Name] [Phone #]

[pharmaceutical company] Vaccine Health Science Consultant: [Name] [Phone #]

A.2 4 Pillars™ Immunization Toolkit Immunization Improvement Readiness Questionnaire

The following items describe some of the strategies practices might use to maximize adult vaccination. Please read each item and check the appropriate column as to whether your practice: 1) is not currently using; 2) is currently using sometimes; 3) is using routinely; or 4) has not used but is interested in trying.

	My practice is:			
Strategies	Not using	Using sometimes	Using routinely	Interested in trying
1. Vaccinate/offer vaccines at chronic and acute care visits	☐	☐	☐	☐
2. Administer two indicated vaccines at the same visit (flu and pneumococcal vaccines, flu and Tdap vaccines)	☐	☐	☐	☐
3. Review patient immunization records during vital signs/rooming	☐	☐	☐	☐
4. Offer vaccines during regular office hours for walk-ins	☐	☐	☐	☐
5. Offer other express vaccination services e.g., evening and/or weekend flu vaccine only sessions	☐	☐	☐	☐
6. Set up a dedicated area as a vaccination station for walk-ins or nurse vaccination visits	☐	☐	☐	☐
7. Administer influenza vaccine as early as it is available (as early as August)	☐	☐	☐	☐
8. Continue to offer flu vaccine until influenza season has ended (as late as February)	☐	☐	☐	☐
9. On-hold message promotes vaccination and/or reminds patients to get vaccinated	☐	☐	☐	☐

	Strategies	My practice is: Not using	Using sometimes	Using routinely	Interested in trying
10.	During flu season reception desk staff reminds patients that flu vaccine is available	☐	☐	☐	☐
11.	After-visit summary recommends vaccination for next visit if patient is eligible and was not vaccinated.	☐	☐	☐	☐
12.	Generate EMR reports to determine all patients who are eligible and not vaccinated	☐	☐	☐	☐
13.	Actively reach out to patients (call, letter, email) who are eligible and not vaccinated	☐	☐	☐	☐
14.	The current ACIP Adult Immunization schedule is posted/visible/easily accessible	☐	☐	☐	☐
15.	Vaccine educational materials are readily available in the waiting room and/or the exam rooms	☐	☐	☐	☐
16.	Vaccination fliers are posted in the waiting and/or the exam rooms	☐	☐	☐	☐
17.	Staff has reviewed specific, tested, culturally appropriate statements to encourage vaccination	☐	☐	☐	☐
18.	Staff states that the physicians recommend vaccines	☐	☐	☐	☐
19.	Most staff are vaccinated and expresses personal support for vaccination with patients	☐	☐	☐	☐
20.	Staff recommends reliable vaccination websites to patients (Families Fighting Flu; IAC; PKIDS)	☐	☐	☐	☐
21.	New hires are in-serviced about vaccination priorities	☐	☐	☐	☐
22.	Clinical staff independently screens patients for vaccine eligibility, contraindications and precautions	☐	☐	☐	☐
23.	Clinical staff administers influenza vaccines using standing order protocols	☐	☐	☐	☐

	Strategies	My practice is: Not using	Using sometimes	Using routinely	Interested in trying
24.	Clinical staff administers Tdap vaccines using standing order protocols	☐	☐	☐	☐
25.	Clinical staff administers PPSV vaccines using standing order protocols	☐	☐	☐	☐
26.	Clinical staff administers PCV vaccines using standing order protocols	☐	☐	☐	☐
27.	Clinical staff administers Zoster vaccines using standing order protocols	☐	☐	☐	☐
28.	Staff documents in EMR the reason(s) for vaccine refusal	☐	☐	☐	☐
29.	Staff updates EMR with the vaccines given elsewhere (pharmacies)	☐	☐	☐	☐
30.	Vaccination reports are reviewed and shared with staff	☐	☐	☐	☐
31.	A staff member or provider serves as the motivational leader for vaccination activities (immunization champion)	☐	☐	☐	☐
32.	The immunization champion is an individual in a leadership role in the practice	☐	☐	☐	☐
33.	Immunization champion meets regularly with other staff members to update them on progress and discuss other strategies to improve vaccination rates	☐	☐	☐	☐
34.	Immunization champion updates staff on the use and administration of new vaccines, new schedules, and new or revised recommendations as they become available	☐	☐	☐	☐
35.	Motivation to improve vaccinations is fostered by rewards, competition, motivational messaging, etc.	☐	☐	☐	☐
36.	Strategies to improve vaccination are evaluated to determine effectiveness and are modified as needed	☐	☐	☐	☐

Appendix B 3 Meeting Kick-Off Series Agendas

B.1 Practice Leadership Meeting

Attendees:

- Office Manager, Lead Physician(s), Facilitator

Expected duration:

- 30 mins

Meeting Objectives:

- Explain "what" the goal is (data/rates)
- Explain "why" they were selected
- Explain "how" they will implement & measure (4Pillars)
- Define Collaboration with Facilitator
- Reintroduce Letter from CEO
- Review IC expectations, punch list & support

Activities

- Overview of project timeline & Packet Information

Mission Statement/Project Goals:

"The goal of the Immunization Initiative is to support increasing immunization rates in adults. Incorporating adult immunization into the process of vital signs will improve the quality of life for our patients and the community in general. The intention of this group is to educate and reinforce the role of the healthcare worker to accomplish this task in the physician office."

Next Steps:

- Facilitator to check- in 2 days later for post meeting questions
- Facilitator to pick up skills assessment form within 1-week post meeting
- Facilitator set next appointment and gain Outlook access to IC calendar

B.2 Immunization Champion Coaching Meeting

Attendees:

- IC, Facilitator
- Optional but encouraged: Office Manager

Expected duration:

- 30 mins

Meeting Objectives:

- Review 4 Pillars™ Vaccine Administration Readiness Questionnaire
- Review office data/stats
- Introduce 4Pillars™ website & Pillar selections
- Review how to log on to site & utilization
- Introduce disease resource handout for patients
- Review IC expectations

Next Steps/Follow Up:

- IC set kick off meeting date with staff

- Facilitator to have touch points prior to kick off meeting to assist IC in meeting preparation
- Expectation that Facilitator will be having touch points at least 1x/month with office as initiative rolls out; but more or less as needed

B.3 All Staff Kick Off Meeting

Attendees:

- IC, Office Manager, Facilitator, Lead Physician(s), Biller, any staff involved with immunization Process

Expected duration:

- 1 hr.

Meeting Objectives:

- IC /OM to present to staff explanation of initiative
- Review office immunization rate data
- Review Skills Assessment Checklist
- Review 4Pillars™ & selected strategies
- Explain Facilitator partnership
- Review office procedure/SOP/Resources
- Q & A from staff
- Set next appointment with office

Next Steps:

- Obtain agreement from practice & Facilitator on collaboration

Appendix C Location Aggregated Data

		Patients					
		sum	mean	std	min	max	median
Time period	Vaccine						
Baseline	Flu	70,503.00	1,762.58	1,142.25	260.00	5,908.00	1,487.50
	PCV	70,503.00	1,762.58	1,142.25	260.00	5,908.00	1,487.50
	Pneumo	70,503.00	1,762.58	1,142.25	260.00	5,908.00	1,487.50
	Td	70,503.00	1,762.58	1,142.25	260.00	5,908.00	1,487.50
	Tdap	70,503.00	1,762.58	1,142.25	260.00	5,908.00	1,487.50
	Zost	70,503.00	1,762.58	1,142.25	260.00	5,908.00	1,487.50
Follow-up	Flu	81,078.00	2,026.95	1,271.17	338.00	6,363.00	1,740.00
	PCV	81,078.00	2,026.95	1,271.17	338.00	6,363.00	1,740.00
	Pneumo	81,078.00	2,026.95	1,271.17	338.00	6,363.00	1,740.00
	Td	81,078.00	2,026.95	1,271.17	338.00	6,363.00	1,740.00
	Tdap	81,078.00	2,026.95	1,271.17	338.00	6,363.00	1,740.00
	Zost	81,078.00	2,026.95	1,271.17	338.00	6,363.00	1,740.00

		Number of visits during time period					
		sum	mean	std	min	max	median
Time period	Vaccine						
Baseline	Flu	164,971.00	4,124.27	2,923.96	847.00	14,968.00	3,299.00
	PCV	246,921.00	6,173.02	4,309.30	1,284.00	22,059.00	5,038.50
	Pneumo	246,921.00	6,173.02	4,309.30	1,284.00	22,059.00	5,038.50
	Td	246,921.00	6,173.02	4,309.30	1,284.00	22,059.00	5,038.50
	Tdap	246,921.00	6,173.02	4,309.30	1,284.00	22,059.00	5,038.50
	Zost	246,921.00	6,173.02	4,309.30	1,284.00	22,059.00	5,038.50
Follow-up	Flu	191,584.00	4,789.60	3,266.89	935.00	17,223.00	3,908.50
	PCV	282,279.00	7,056.98	4,695.81	1,420.00	24,402.00	5,746.00
	Pneumo	282,279.00	7,056.98	4,695.81	1,420.00	24,402.00	5,746.00
	Td	282,279.00	7,056.98	4,695.81	1,420.00	24,402.00	5,746.00
	Tdap	282,279.00	7,056.98	4,695.81	1,420.00	24,402.00	5,746.00
	Zost	282,279.00	7,056.98	4,695.81	1,420.00	24,402.00	5,746.00

		Vaccine eligible					
		sum	mean	std	min	max	median
Time period	Vaccine						
Baseline	Flu	55,838.00	1,395.95	910.70	209.00	4,745.00	1,228.00
	PCV	50,420.00	1,260.50	823.65	151.00	4,132.00	1,068.00
	Pneumo	17,346.00	433.65	320.74	45.00	1,677.00	381.50
	Td	337.00	8.43	10.67	0.00	50.00	5.00
	Tdap	43,154.00	1,078.85	722.84	66.00	3,461.00	1,017.00
	Zost	46,725.00	1,168.12	769.57	173.00	3,717.00	1,078.50
Follow-up	Flu	65,029.00	1,625.72	1,053.50	266.00	5,246.00	1,371.00
	PCV	17,218.00	430.45	330.24	50.00	1,848.00	341.00
	Pneumo	21,258.00	531.45	381.56	66.00	2,027.00	458.50
	Td	1,221.00	30.52	30.06	3.00	133.00	19.00
	Tdap	36,031.00	900.77	623.61	72.00	3,357.00	770.00
	Zost	47,040.00	1,176.00	789.11	182.00	4,258.00	1,012.50

		Vaccine administered elsewhere					
		sum	mean	std	min	max	median
Time period	Vaccine						
Baseline	Flu	4,877.00	121.92	87.01	5.00	374.00	107.50
	PCV	708.00	17.70	14.03	0.00	52.00	13.50
	Pneumo	530.00	13.25	10.31	2.00	53.00	11.00
	Td	20.00	0.50	1.01	0.00	4.00	0.00
	Tdap	619.00	15.47	13.66	1.00	59.00	12.00
	Zost	1,640.00	41.00	28.36	7.00	131.00	33.00
Follow-up	Flu	4,634.00	115.85	76.01	15.00	359.00	98.00
	PCV	508.00	12.70	8.42	1.00	33.00	10.50
	Pneumo	456.00	11.40	7.31	1.00	30.00	10.00
	Td	8.00	0.20	0.41	0.00	1.00	0.00
	Tdap	769.00	19.23	18.47	2.00	84.00	14.00
	Zost	641.00	16.02	12.59	1.00	50.00	12.50

		Immunized					
		sum	mean	std	min	max	median
Time period	Vaccine						
Baseline	Flu	37,799.00	944.98	648.66	152.00	3,115.00	737.50
	PCV	9,461.00	236.53	190.13	23.00	718.00	157.00
	Pneumo	4,706.00	117.65	91.99	21.00	369.00	90.50
	Td	33.00	0.82	1.32	0.00	5.00	0.00
	Tdap	5,612.00	140.30	137.23	9.00	807.00	118.00
	Zost	3,816.00	95.40	67.97	16.00	362.00	83.50
Follow-up	Flu	25,002.00	625.05	466.09	123.00	2,600.00	499.50
	PCV	6,200.00	155.00	93.93	16.00	388.00	132.50
	Pneumo	5,524.00	138.10	95.16	18.00	448.00	110.50
	Td	10.00	0.25	0.49	0.00	2.00	0.00
	Tdap	3,723.00	93.08	59.41	15.00	219.00	79.00
	Zost	1,809.00	45.23	35.29	5.00	164.00	32.00

		Vaccine missed opportunities rate				
		mean	std	min	max	median
Time period	Vaccine					
Baseline	Flu	0.3476	0.1112	0.1188	0.6932	0.3424
	PCV	0.5843	0.0917	0.3774	0.7710	0.5908
	Pneumo	0.1824	0.0743	0.0584	0.3976	0.1711
	Td	0.0051	0.0063	0.0000	0.0271	0.0026
	Tdap	0.5170	0.1642	0.1495	0.8015	0.5178
	Zost	0.6006	0.1248	0.3521	0.8446	0.6187
Follow-up	Flu	0.6362	0.1363	0.2305	0.7888	0.6635
	PCV	0.1255	0.0678	0.0424	0.3561	0.1143
	Pneumo	0.1883	0.0643	0.0971	0.3633	0.1830
	Td	0.0151	0.0108	0.0019	0.0494	0.0140
	Tdap	0.3831	0.1370	0.1106	0.7027	0.3762
	Zost	0.5363	0.1195	0.3049	0.7921	0.5399

		Vaccination rate				
		mean	std	min	max	median
Time period	**Vaccine**					
Baseline	**Flu**	0.5339	0.0834	0.2662	0.7071	0.5462
	PCV	0.1310	0.0569	0.0325	0.2870	0.1206
	Pneumo	0.0674	0.0240	0.0321	0.1435	0.0620
	Td	0.0006	0.0011	0.0000	0.0044	0.0000
	Tdap	0.0755	0.0381	0.0249	0.2083	0.0653
	Zost	0.0562	0.0169	0.0209	0.0940	0.0554
Follow-up	**Flu**	0.3169	0.1038	0.2013	0.6432	0.2839
	PCV	0.0783	0.0170	0.0147	0.1150	0.0769
	Pneumo	0.0685	0.0204	0.0206	0.1417	0.0683
	Td	0.0002	0.0004	0.0000	0.0018	0.0000
	Tdap	0.0484	0.0180	0.0161	0.0962	0.0467
	Zost	0.0236	0.0108	0.0037	0.0508	0.0210

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