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Cost Effectiveness of the 4 Pillars™ Practice Transformation Program to Improve Vaccination of Adults Aged ≥65 years

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Abstract

Objectives—Interventions to improve adult vaccination uptake in primary care have met with limited success, raising questions about whether the benefits to patients are worth the time and resources necessary to implement them. Here we examine the cost effectiveness of an intervention to increase pneumococcal, influenza and pertussis-containing vaccine uptake among adults ≥65 years of age in primary care practices.

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Stocks		x		x		x		x
Royalties		x		x		x		x
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The sponsors had no role in the design, methods, data collection, analysis and preparation of paper.

Design—Markov decision analysis model, estimating the cost-effectiveness of the 4 Pillars™ Practice Transformation Program compared with no intervention.

Setting—Diverse primary care practices in 2 US cities

Participants—Clinical trial patients aged 65 years and older. Vaccination rates and intervention costs were derived from a randomized controlled cluster trial. Other parameters were derived from the medical literature and CDC data. All parameters were individually and simultaneously varied over their distributions.

Measurements—Quality adjusted life years (QALYs), public health outcomes, and costs

Results—With the intervention program and extrapolating over 10 years, there would be ~60,920 fewer influenza cases, 2,031 fewer pertussis cases, and 13,842 fewer pneumococcal illnesses among adults ≥65 years. Compared to no intervention, total per-person vaccination and illness costs with the intervention were $1.60 higher with a concurrent increase in effectiveness of 0.0031 QALYs, or $512 per QALY gained. In sensitivity analyses, no individual parameter variation caused the intervention to cost >$20,000 per QALY gained.

Conclusions—Implementing an intervention based on the 4 Pillars™ Practice Transformation Program is a cost-effective undertaking in primary care practices for patients ≥65 years old with predicted public health benefits.

Keywords

adult vaccination; cost effectiveness; influenza vaccine; pneumococcal vaccine; Tdap vaccine

Introduction

The 4 Pillars™ Practice Transformation Program, also known as the 4 Pillars™ Toolkit (Toolkit), is a primary care practice improvement aid focused on changing behavior using evidence-based strategies (1, 2) that are organized into four domains. The pillars are: 1. Convenient vaccination services; 2. Communication with patients about the importance of immunization and the availability of vaccines; 3. Enhanced office systems to facilitate immunization; and 4. Motivation through an office immunization champion who monitors progress and encourages adherence to vaccination-promoting office procedures to improve vaccine uptake (3). The Toolkit has been tested in several trials and found to be moderately effective for increasing immunization rates in adults (3, 4) and children (5). The question remains whether the benefits from an intervention to improve adult vaccination rates are worth the effort of implementing a set of long-term patient-, provider-, and office system changes. From the provider's perspective, there is a financial incentive to increase vaccine uptake, as the Center for Medicare and Medicaid Services has made reporting of influenza and pneumococcal vaccines a requirement for providers to avoid negative payment adjustments (6). Moreover, in some states, administration fees adequately reimburse providers for offering adult vaccines. Conversely, there are costs associated with implementing some of the Toolkit strategies such as educating and training staff, writing standing order protocols, establishing new policies, purchasing vaccine informational materials, and making or sending vaccination reminders.

The Toolkit is an online source of evidence-based practices for implementing a quality control project that contains background information on vaccines, case studies and best practices, strategies for making changes in each of the 4 Pillars' domains, resources, links to other reliable vaccination sites and a dashboard to assist practices with choosing strategies, mapping the change process and tracking progress. The purpose of this study was to examine the cost effectiveness of an intervention to increase pneumococcal vaccine uptake among adults ≥65 years of age in primary care practices using the Toolkit. A Markov decision analysis model was used to estimate the cost effectiveness of using the Toolkit to improve vaccination rates compared with no intervention.

Methods

Vaccination rates and intervention costs were derived from a randomized controlled cluster trial conducted in two U.S. cities (Pittsburgh and Houston) among diverse populations and medical practice settings. (4) The trial was approved by the Institutional Review Boards of the University of Pittsburgh, Baylor College of Medicine and Harris Health System.

The intervention using the Toolkit was designed to assist practices in improving uptake of influenza, pneumococcal and tetanus-pertussis-diphtheria (Tdap) vaccines. Vaccination rates for each vaccine are based on those observed in the trial and improvements in rates post intervention. (4) To simplify modeling procedures, we assumed that the probability of receiving each vaccine was not correlated with the probability of receiving other vaccines. We also assumed that the probabilities of receiving the two pneumococcal vaccines (23-valent pneumococcal polysaccharide vaccine (PPSV) and 13-valent pneumococcal conjugate vaccine (PCV13)) were equal. This assumption was tested in sensitivity analyses.

Vaccine effectiveness (VE) was used to determine protection from illness, with illness risk calculated as the illness attack rate for the ≥65-year-old population multiplied by 1 minus VE. Influenza VE was based on medical literature and CDC data, and was varied widely to reflect recent trends in vaccine protection (7–9), assuming yearly revaccination. Tdap VE only considered pertussis prevention, due to the rarity of tetanus and diphtheria, and was calculated as average pertussis VE over the 10-year-model time horizon using recent data on waning pertussis protection post vaccination. (10) Pneumococcal vaccine effectiveness was similarly averaged, using waning parameters as outlined by a prior Delphi expert panel adjusted by observed PCV13 effectiveness from a large randomized trial (11, 12). Pneumococcal VE was then adjusted by the relative likelihood of disease due to each vaccine's serotypes, based on published reports of U.S. epidemiologic surveillance data (13). PPSV was assumed to prevent invasive pneumococcal disease (IPD) from vaccine serotypes; PCV13 was assumed to prevent vaccine-serotype IPD and non-bacteremic pneumococcal pneumonia (NPP).

U.S. databases and medical literature data (7–9, 14) were used for parameters describing vaccine costs and effectiveness, illness rates and costs, and quality of life utilities. The analysis took a societal perspective, following the reference case recommendations of the U.S. Panel on Cost Effectiveness in Health and Medicine (15). The 4 Pillars intervention cost was estimated from questionnaire data obtained from intervention study sites regarding

personnel and material costs to introduce and maintain the intervention. Improved vaccine uptake was that observed at the end of the 2-year trial. All model parameters are depicted in Table 1.

A decision tree model was used to estimate the cost effectiveness of the Toolkit for improving vaccination rates compared to no intervention in persons aged 65 years and older (Supplementary Figure S1). Identical hypothetical cohorts traversed the two modeled strategies. The sum of the baseline vaccine uptake and observed percentage point improvement was held constant over the 10-year-model time horizon in the base case analysis. To account for illness-related loss of quality and duration of life, quality adjusted life years (QALYs) lost due to illness was used as a measure of vaccine effectiveness. Future costs and effectiveness were discounted at 3% per year.

To test the robustness of model results, all parameters were individually varied over the ranges listed in Table 1. In addition, in a probabilistic sensitivity analysis, all parameters were simultaneously varied over distributions 3000 times. Beta distributions approximating the listed ranges were assigned to probabilities and utilities; gamma distributions were used for costs and time lost due to illness.

Results

Based on model results considering public health outcomes (Table 2), improvements in vaccine uptake should lead to substantial decreases in illness frequency. Over the 10-year-model time horizon, influenza case incidence decreased 1.8 percentage points (from 37.3% to 35.5% of the cohort), with comparable relative decreases in hospitalization and deaths due to influenza. Smaller decreases in pertussis illness, invasive pneumococcal disease and non-bacteremic pneumococcal pneumonia occurred (0.6 PP, 0.009 PP and 0.4 PP, respectively). In 2014, the U.S. population aged 65 years old was 3,384,449. With an intervention program in place and extrapolating over 10 years, there would be approximately 60,920 fewer influenza cases, 2,031 fewer pertussis cases, and 13,842 fewer pneumococcal illnesses among this age group.

In the cost-effectiveness analysis (Table 3), total per-person vaccination and illness costs were $1.60 higher with the Toolkit intervention in place compared to no program, with a concurrent increase in effectiveness of about 0.0031 fewer QALYs lost (or about 1.1 days). Thus, the Toolkit cost $512 per QALY gained.

In sensitivity analyses to test the robustness of these results, no individual parameter variation, as listed in Table 1, caused the intervention to cost >$20,000 per QALY gained. Variation of only 2 parameters caused the favored strategy to change when lowering the threshold to $10,000/QALY gained: a) when the program-related absolute increase in influenza vaccination was below 0.9% (base case = 5%); or b) when influenza VE was less than 25.1% (base case = 59.0%). Results were insensitive to individual variation of all other parameters over their listed ranges. For example, if the program cost is increased to the high end of its range, $2.26, from its base case value of $1.78 per eligible patient, the program will cost $1,857/QALY gained. Increasing program costs to $5/patient will make the

program cost $9,533/QALY gained, while the program will be cost saving if per-patient costs are <$1.60. In the base case analysis, we assumed patients received both pneumococcal vaccines if they received any pneumococcal vaccination; if they receive both only half the time, the intervention will cost, at most, $2,956/QALY gained. Conversely, varying several parameters in clinically plausible ranges (Supplementary Figure S2) caused the intervention to become cost saving and more effective than no intervention, including a broad mix of disease incidence, vaccine effectiveness, and cost parameter variations. Finally, in a probabilistic sensitivity analysis, where all parameters were simultaneously varied, the Toolkit intervention was cost saving in 35.4% of model iterations and favored in 98.6% at a $50,000/QALY gained, a commonly cited cost-effectiveness benchmark (16).

Discussion

In a cost-effectiveness analysis largely based on clinical trial data, we found that an intervention designed to increase vaccination rates in adults cost $512 per QALY gained. In general, interventions costing less than $20,000 per QALY gained are considered “good buys,” an investment in health improvement that is very reasonable to make (17). In the literature and in the absence of U.S. cost-effectiveness criteria, benchmark values of $50,000 or $100,000 per QALY gained are often cited as economically reasonable in the U.S. (16, 18). In addition, in sensitivity analyses, individual variation of model parameters within plausible ranges could not increase the Toolkit intervention cost to $20,000 or more per QALY gained, highlighting the robustness of the intervention’s favorability. Plausible parameter variation could make the intervention less expensive and more effective than no intervention.

In prior work, we explored the cost effectiveness of hypothetical vaccination programs to increase influenza and pneumococcal vaccine uptake and decrease vaccination disparities in elderly minority patients (19–21). We found these programs economically favorable in general, but with higher costs per QALY gained than those found in this analysis. Those higher costs per QALY were driven mainly by differences in modeled program costs, program-related improvements in vaccine uptake, and illnesses prevented. In prior work examining both influenza and pneumococcal vaccines (21), programs of varying intensity were estimated to cost from $2 to $17.84, much more than our empiric cost $1.78 (range $0.70–2.26), while modeling somewhat greater improvements in vaccine uptake than those observed in the trial. In addition, the prior analyses modeled pneumococcal vaccine effectiveness only against invasive pneumococcal disease and not against non-bacteremic pneumonia; in the present analysis, protection against both infections is modeled.

Indirect (herd immunity) effects are not modeled in this analysis, a potential limitation. We justify this choice based on data suggesting that the indirect effect of vaccinating the elderly is much less than that seen when other age groups (e.g., children) are vaccinated, thus the relative indirect effect on the population of vaccinating the elderly, compared to other groups, is small. However, if such effects were considered, the cost effectiveness of the Toolkit intervention for the elderly would likely become even more favorable than the results reported here. The costs did not include the research personnel costs because these would not be included in a program using the Toolkit, but initiated by the primary care practice

itself. In older adults, frailty could be an important predictor of influenza vaccine effectiveness and influenza severity; frailty was not directly modeled, another limitation of our analysis.

Effectuating significant long term changes in adult vaccination rates has been an elusive goal. Hence, efforts to improve rates continue to be undertaken. Yet with modest short term improvements in vaccination uptake and limited reach of many programs, the question arises, “Do the improvements in vaccination rates justify the effort required by the primary care practice?” This cost-effectiveness analysis offers a resounding “Yes” to that question. At an estimated cost per eligible patient of $1.78 per year, few practices would not be able to implement an intervention using the 4 Pillars™ Practice Transformation Program.

We conclude that implementing an intervention based on the 4 Pillars™ Practice Transformation Program in an effort to increase vaccination among adults ages 65 years and older is a cost effective undertaking in primary care practices. Even modest improvements in uptake can have a large impact on the health of these at risk individuals.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Parameter values used in cost-effectiveness modeling

Parameter	Base case	Range	Source
Probabilities	*%*	*%*	
Vaccination probability with no program			
Influenza	66	36–74	(4)
Tdap	25	4–54	(4)
Pneumococcal vaccines	71	31–81	(4)
Absolute increase in vaccine uptake with program			
Influenza	5	0–15	(4)
Tdap	10	0–26	(4)
Pneumococcal vaccines	10	0–18	(4)
Vaccine effectiveness			
Influenza	59.0	20–67	(7–9)
Tdap (10 year average)	24.5	0–95	(10)
Pneumococcal vaccines (10 year average)			
Vaccine type invasive pneumococcal disease (IPD)	54.2	40–68	(12)
Vaccine type non-bacteremic pneumonia (NPP)	38.3	28–48	(11, 12)
Pneumococcal illness serotype prevalence			
PCV13 serotypes	30.7	0–50	(13)
PPSV serotypes	67.6	50–85	(13)
Probability of illness without vaccinations (yearly)			
Influenza	9.0	6.6–11.4	(22)
Pertussis	0.257	0.138–0.464	(23)
Invasive pneumococcal disease	0.023	0.0046–0.073	(24)
Non-bacteremic pneumococcal pneumonia	3.78	0.54–12.1	(24)
Relative likelihood of outpatient treatment (vs. inpatient)	83.1	70–96	(24)
Case-hospitalization, influenza	4.21	1.4–7	(22)
Case-mortality, influenza	1.17	0.37–2	(22)
Pertussis severity relative likelihood			
Mild	14	8–20	(14)
Relative likelihood of treatment (vs. no treatment)	70.7	50–90	(14)
Moderate	74	63–85	(14)
Severe (hospitalized)	12	6–18	(14)
Encephalopathy, given severe	1.43	0–3	(14)
Mortality, given severe	0.86	0–2	(14)
Costs (base year 2015)	*US$*	*US$*	*US$*
Vaccines			
Influenza	10.69	6.64–32.75	(25)
Tdap	37.55	20.18–42.61	(25)
Pneumococcal polysaccharide	7.89	2.66–13.00	(25)
Pneumococcal conjugate	15.96	9.61–22.00	(25)

Parameter	Base case	Range	Source
Vaccine administration, per vaccine	25.51	20–30	(26)
Implementation program, per eligible person	1.78	0.70–2.26	*a*
Illness costs			
Mild pertussis, when treated	305	153–1525	(14)
Moderate pertussis	424	212–2120	(14)
Severe pertussis	7,824	4,000–11,500	(14)
Influenza (average, all severities)	1,655	432–3,706	(22)
Pneumococcal disease (average, all severities)	3,422	671–16,056	(24)
Utilities, disutilities, and durations			
Utilities			
Pertussis			
Mild	0.9	0.8–0.99	(14)
Moderate	0.85	0.75–0.95	(14)
Severe	0.81	0.6–0.9	(14)
Encephalopathy	0.2	0–0.4	(14)
Non-bacteremic pneumococcal pneumonia			
Inpatient	0.2	0–0.5	(12)
Outpatient	0.9	0.7–1	(27)
Invasive pneumococcal disease	0.2	0.0.5	(12)
Disability post pneumococcal disease	0.4	0.2–0.6	(12)
Disutilities (quality adjusted life years lost)	*QALY*	*QALY*	*QALY*
Non-hospitalized influenza	0.0021	0–0.02	(22)
Hospitalized influenza	0.042	0.02–0.08	(22)
Illness death (discounted)	10.25	5–15	(28)
Illness duration (days)			
Pertussis	87	30–100	(14)
Non-bacteremic pneumococcal pneumonia			
Inpatient	27	20–40	(27)
Outpatient	18	10–25	(27)
Invasive pneumococcal disease	27	20–40	(27)

[a] Calculation from unpublished 4 Pillars data

Table 2

Public health results – proportion of the cohort with illness over 10 years

	Influenza			Pertussis			Invasive pneumococcal disease		Nonbacteremic pneumococcal pneumonia		
Strategy	**Total cases %**	**Hospitalized %**	**Deaths %**	**Total cases %**	**Hospitalized %**	**Deaths %**	**Total cases %**	**Deaths %**	**Total cases %**	**Hospitalized %**	**Deaths %**
No program	37.3	2.01	0.436	2.37	0.285	0.00245	0.169	0.034	29.2	4.93	0.21
Program	35.5	1.91	0.415	2.31	0.278	0.00239	0.160	0.032	28.8	4.86	0.23

Table 3

Cost-effectiveness analysis results

Strategy	Cost	Incremental Cost	Effectiveness (QALYs lost)	Incremental Effectiveness (QALYs)	Incremental CE Ratio
No program	$1,930.27	-	−0.1016	-	-
Program	$1,931.87	$1.60	−0.0985	0.0031	$512

QALY = quality adjusted life year, CE = cost-effectiveness