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Cost-Effectiveness of Influenza Vaccination of Older Adults in the Emergency Department Setting

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Abstract

Objectives—Adults over 50 are at greater risk for death and severe disability from influenza. Persons in this age group, however, are frequently not vaccinated, despite extensive efforts by physicians to provide this preventive measure in primary care settings. We performed this study to determine if influenza vaccination of older adults in the Emergency Department (ED) may be cost-effective.

Methods—Using a probabilistic decision model with quasi-Markov modeling of a typical influenza season, we calculated costs and health outcomes for a hypothetical cohort of patients using parameters from the literature. Three ED-based intervention strategies were compared: (1) no vaccination offered; (2) vaccination offered to patients over age 65 years (limited strategy); and (3) vaccination offered to all patients age 50 years and older (inclusive strategy). Outcomes were measured as costs, lives saved, and incremental costs per life saved. We performed deterministic and probabilistic sensitivity analyses.

Results—Vaccination of patients age 50 years and older results in an incremental cost of \$34,610 per life saved when compared to the no vaccination strategy. Limiting vaccination to only those over age 65 results in an incremental cost of \$13,084 per life saved. Results were sensitive to changes in vaccine cost, but were insensitive to changes in other model parameters.

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Conclusions—Vaccination of older adults against influenza in the ED setting is cost-effective, especially for those over age 65 years. EDs may be an important setting for providing influenza vaccination to adults who may otherwise have remained unvaccinated.

Keywords

Influenza; Emergency Department; Cost-effectiveness; Vaccination; Preventive Health

Introduction

Influenza is a major cause of illness and a significant public health problem that affects a large proportion of the United States population each year. While media attention has recently focused on then pandemic swine influenza A (H1N1) strain, every year seasonal influenza A and B consistently contribute to approximately 40,000 deaths, mostly in the elderly population,¹ making influenza the seventh leading cause of death in the United States.²³ In addition, the annual economic burden of influenza is estimated as high as \$87 billion in the United States alone.⁴ With increasing public awareness of morbidity and mortality associated with influenza, healthcare providers and health delivery systems have a unique opportunity to improve influenza prevention. Increasingly, public health interventions are being seen as important components of emergency care. Evidence supports emergency department (ED) screening for alcoholism, HIV, and various malignancies as well as delivery of vaccinations for other conditions such as pneumococcal pneumonia⁵⁻⁷. While there is some debate among emergency physicians regarding the appropriateness of adding each new intervention to already overburdened departments⁸, ED's have been providing preventive care such as tetanus vaccination for many years⁹.

Vaccination is the main public health intervention for mitigating the effects of influenza outbreaks by preventing cases and reducing complications.¹⁰⁻¹² Prior studies have found influenza vaccination to be both effective and cost saving, especially in the elderly and high-risk patients. Notwithstanding recommendations by the Advisory Committee on Immunization Practices (ACIP) for the vaccination for all older adults, only 36% of adults over 65 years of age receive the vaccine on a yearly basis.¹³ Recent studies have demonstrated the potential effectiveness of ED-based programs for increasing influenza vaccination rates in communities.¹⁴ In addition, ACIP has advocated the administration of influenza vaccine in the ED setting.¹³ Older adults represent a group at high risk for complications of influenza, and also the fastest growing proportion of ED patients¹⁵. Unfortunately, very few EDs offer influenza vaccination⁸, possibly because of uncertainty regarding the cost-effectiveness of this specific public health measure.

These findings illustrate the need to expand vaccination efforts to increase coverage to health care settings beyond primary care physician offices while limiting vaccination costs.¹⁶⁻¹⁸ We conducted this study to determine the cost-effectiveness of influenza vaccination of older adult patients in the ED setting. Computer simulations were conducted to measure costs, lives saved, and cost per life saved among a hypothetical cohort of adults 50 years and older, with the objective of assessing the effects and costs of providing the influenza vaccination in the ED setting.

Methods

Study Design

We conducted a decision analytic study using quasi-Markov modeling to assess the comparative cost-effectiveness of different public health intervention strategies for influenza vaccination of older adult patients in the ED setting. Three ED-based intervention strategies were compared: (1) no vaccination offered; (2) vaccination offered to patients over age 65 years (i.e. limited strategy); and (3) vaccination offered to all patients age 50 years and older (i.e. inclusive strategy). We performed an extensive literature review to obtain values for model parameters which included best available evidence regarding costs (Table 1) as well as utilities and outcome probabilities (Table 2). Analyses were conducted using TreeAge Pro 2009 (Williamstown, Massachusetts). Findings were expressed in terms of costs in 2008 United States dollars, lives saved, and incremental costs per life saved.

Markov transition states for the model are presented in Figure 1. Each week, based on preset probabilities, individuals in the study population transition to different states of healthy and unvaccinated, vaccinated, or influenza diseased. Once vaccinated, individuals may stay vaccinated or move into influenza disease states. Both vaccinated and unvaccinated individuals visit EDs for unrelated complaints, and while in the ED those who are unvaccinated may be offered the vaccine. Our quasi-Markov model utilized an underlying oscillating prevalence to estimate weekly influenza attack rates over the course of the season. True attack rates vary based on weather, changing patterns of social interaction, varying host immunity, and viral properties.¹⁹ We modeled this phenomenon by varying weekly attack rates with a simple half sine wave peaking at the center of the 24-week season, with a cumulative incidence calibrated to the seasonal incidence of 6.6% described in the literature.⁴

Study Setting and Population

We modeled a hypothetical population of 100,000 adults aged 50 years and older who proceeded through a 24-week period with discrete weekly steps to simulate a typical influenza season. US census data was used to model patient demographics based on a theoretical random sampling of US citizens in an effort to simulate the adult population of a generic ED catchment area.²⁰ ED visit rates were estimated from the National Hospital Ambulatory Medical Care Survey.²¹ Patients were stratified within the model by age and presence of high risk co-morbidities. We assumed that a certain proportion of the population would be vaccinated at sites outside of EDs over the course of the first 8 weeks of the season based on ACIP reported vaccination rates.¹³

Measures

This study modeled the administration of the parenterally delivered trivalent inactivated vaccine (TIV). This is the formulation currently recommended for all adults 50 and over and is the only FDA approved influenza vaccine for this population.¹³ It was difficult to arrive at a consensus value for the effectiveness of this vaccine for several reasons. Yearly variations in the match between vaccine and circulating strains, lack of randomized controlled trials, and a wide variety of case definitions and outcomes used to infer vaccine effectiveness in

cohort studies all complicate attempts to aggregate data.¹²¹³ Vaccination effectiveness was modeled as a 60% reduction of all influenza endpoints in those 50 through 65 years of age. Effectiveness was reduced to a 50% reduction in all endpoints in those over 65, as it is likely that the overall effectiveness of the vaccine decreases with increasing age, due to decreased immunogenic response.¹²¹³²² Sensitivity analyses were conducted over a wide range of values based on conservative review of published data (see Table 2).

Cost of the TIV vaccine administration outside of the ED was estimated at \$29.73.²² In the base case, the cost of the vaccine in the ED was assumed to be 15% more expensive than in a traditional primary care office setting at \$34.19. This cost difference was added in an attempt to reflect the fact that likely an ED program may be more resource intensive than a program outside of the ED. Due to uncertainty surrounding this figure, a broad range was chosen for sensitivity analysis (95% CI \$19.67-\$48.71), and an individual one-way sensitivity analysis was performed. We also assumed that not all eligible patients would be vaccinated in either the limited or inclusive strategies, as some would be critically ill or leave the ED before receiving vaccination, while others would refuse the intervention. Therefore, we assumed that patients who entered the ED for an unrelated visit would receive vaccination 80.7% of the time in the intervention strategies. This estimate assumed all patients who were transferred, refused, died in the ED or left against medical advice would not receive the vaccine.²¹

Primary Data Analysis

The model tracked the total number of influenza related outcomes for patients in each strategy, as well as the total influenza related medical costs accrued. Incremental cost-effectiveness ratios (ICERs) were calculated as the difference in cost between two strategies divided by the difference in total number of deaths or hospitalizations. These ICERs represent the incremental cost to the payer per life saved by choosing one strategy over another. While the model did not track life expectancies beyond a single influenza season, each influenza death likely represents several years of life lost on average.

Sensitivity Analyses

We conducted a Monte Carlo probabilistic sensitivity analysis in order to vary all model variables simultaneously. Distributions for this analysis are presented alongside baseline values for model costs Table 1 and for probabilities and outcomes in Table 2. These distributions were randomly sampled for each of 100,000 model runs, with the results averaged to establish probability that a given strategy would be dominant at a given willingness-to-pay (WTP) for each life saved. Distributions were created with expected values equal to base case values for each variable. If the original literature did not specify a distribution, a normal distribution was fitted such that the 95% confidence interval presented in the original study was two standard deviations from the mean. In cases where variables represented event probabilities, distributions were capped at a probability of 1.0. In the uncommon occurrence during simulation that probabilities at a given node exceeded 1.0, the probabilities of each branch were algebraically normalized in order to sum to 1. Model complexity prevented the computation of multivariate distributions at chance nodes (recursive variable definitions based on changing weekly disease incidence would require a

separate multivariate distribution for each node of the model at each week for each iteration, which was computationally unfeasible).

We additionally performed one and two-way sensitivity analyses on several variables to assess their individual contributions in the model outcomes. Threshold analyses were first performed on the cost of influenza vaccination in the ED and at outside sites, influenza attack rates, vaccine effectiveness, as well as the probabilities of influenza related outcomes in order to determine the point at which changes to these input parameters resulted in a substantial change in strategy ICERs. The 95% confidence intervals from these variables' distributions were used to provide the range of input for threshold analysis. Those variables that exhibited threshold behavior in the range examined were selected for further one and two-way sensitivity analyses as appropriate.

Results

Costs

In the base case analysis (table 3), total payer costs per 100,000 persons for influenza related treatments and outcomes were as follows: Do-nothing strategy, \$8,409,289; limited strategy, \$8,426,664; inclusive strategy, \$8,457,895.

Deaths Prevented

Table 3 presents the data on excess deaths from influenza over the course of the season. Deaths are presented to several decimal places to make apparent small differences between strategies. The Do-Nothing strategy resulted in a death rate of 39.9 per 100,000 persons per season. The Limited and Inclusive strategies resulted in rates of 38.6 and 38.5 per 100,000 deaths per 100,000 persons per season respectively.

Incremental Cost-Effectiveness

Both intervention strategies implementing vaccination of older patients were cost-effective when compared to the no vaccination strategy, with an ICER of \$34,610 per life saved for the inclusive strategy and \$13,084 per life saved for the limited strategy. When comparing the two interventional strategies to each other, we found that vaccinating ED patients age 50 through 64 years added little effectiveness to the limited strategy while increasing the cost (ICER of \$408,784).

Cost-effectiveness acceptability curves (Figure 2) were constructed using the outcome of the Monte Carlo analysis. The analysis indicated that as WTP approached zero, the no-vaccination strategy had a high probability of being the most cost-effective. At a WTP of \$50,000 to over \$1,000,000 per death avoided, payers would find that the limited strategy was the most cost-effective strategy, with the inclusive strategy becoming more cost effective only at very high WTP.

Sensitivity analyses

Over a wide range of probabilities and costs, the limited strategy remained most cost effective. Costs and probabilities of influenza related complications, despite having a

significant impact on total cost of the model, tended to have a similar effect on all three arms of the model, maintaining similar ICER's between strategies. Parameters which violated this trend were cost of vaccination in the ED and influenza attack rate.

Varying the cost of the ED vaccination administration had the greatest effect on cost-effectiveness of the interventional strategies (fig. 3). In one-way sensitivity analysis with all other variables held equal, if the point estimate of cost of ED vaccination was reduced from \$34.19 to \$30.90, the Limited Strategy dominated (was more effective and less costly than) the Do-Nothing strategy, and below \$28.65 the Inclusive Strategy dominated. As the vaccine became more expensive, both interventional strategies experienced significant decreases in cost-effectiveness. Considering that the point at which cost-savings were achieved when the ED vaccine was very close to the cost of vaccination in the community, an additional two-way analysis was conducted varying both vaccination costs. The model was robust to the fluctuations in the cost of the vaccination at outside sites, and continued to demonstrate cost-savings for the ED vaccine in the same range regardless the outside costs.

The model was also sensitive to the overall attack rate for influenza. As influenza attack rates vary from season to season, a wide sensitivity analysis was conducted on these rates, by multiplying weekly rates by a factor ranging from 0.1 to 10, while maintaining the cosine shape of the incidence curve discussed in the methods section. As seen in fig. 4, between incidence 8.6% and 8.7% , the limited strategy of vaccination for only those older than 65 dominated the do-nothing strategy. Above 8.7% of base incidence, the inclusive strategy dominated both other strategies.

Discussion

Despite ACIP recommendations for influenza vaccination in the ED and evidence that the TIV vaccine is safe and cost-effective in the community, doubts exist regarding the practicality of implementing influenza vaccination strategies in this particular health care setting. We found influenza vaccine administration in the ED setting was cost-effective for the general population above age 50 in the base case scenario. Specifically, we found that subgroups analysis indicated that the majority of the benefits of the vaccine program were realized among patients over the age of 65, who are less likely to be immunized in the community and at greatest risk for serious influenza complications. Our model was sensitive to the cost of vaccine administration in the ED but insensitive to most other model variables.

This model was conducted from a payer perspective. The bulk of vaccine cost-effectiveness studies are conducted from a societal viewpoint, where vaccines gain additional cost-effectiveness by preventing costs associated with the societal burden of disease, such as time lost from work. While a societal perspective is useful in making policy decisions, it is not as applicable for those planning on initiating a program in a single ED. ED payers may not be interested in the amount of time taken off of work for their patient base, but will see the benefit of reducing costs associated with treating cardiac and pulmonary complications of influenza. Our findings show that influenza vaccine administration in the ED setting in patients above age 50 was cost-effective from a payer perspective.

Our computer model provides a theoretical rationale for instituting an influenza vaccination program in the ED setting. Actual costs of vaccine delivery depends on many institutional factors, however our base case estimate of \$34 provides a reasonable goal to achieve for a program aiming at cost-effectiveness. If the vaccine can be delivered at a lower cost, it is possible that vaccination can be accomplished with an actual cost savings to payers by preventing costs associated with influenza morbidity and mortality. Our subgroup analysis indicates the bulk of benefit from the vaccine is achieved in older adults; therefore initiating a program focusing first on those 65 and over would be a reasonable goal.

While our model provides an argument for the economic benefits of a vaccination program, it does not take into account public health arguments for or against vaccination in the ED. Resources used for a vaccination program are inevitably drawn from another area. Regardless of whether an ED intervention is cost effective, preventive measures such as vaccination must be weighed against a department's ability to provide acute care measures. Further, in providing non-acute interventions such as vaccination, EDs may be removing incentive for patients to seek primary care outside the ED, and encourage the practice of using the ED inappropriately. These concerns are valid, however EDs currently provide a large number of interventions which fall under the broad umbrella of preventive medicine. The intervention is well studied and well accepted outside of the ED, and our model indicates that it additionally makes economic sense.

Limitations

The demographics of the ED patients were estimated using US census data for a general population of adults, who visited the ED independent of their risk or vaccination status. While the data is currently unavailable, it is likely that the subset of patients entering the ED during the influenza season have lower rates of vaccination at outside sites and higher rates of comorbidities. These effects were not included in the model but would both act to make the intervention more effective.

As discussed in the methodology section, cost of influenza vaccination in the ED was calculated by adding a 15% premium to the cost of the vaccination in the community. Considering the sensitivity of the model to this input, knowledge of the precise cost would be valuable in the decision making process. The true cost of a vaccination program is difficult to estimate precisely, as it would involve the startup costs of administering the program, actual acquisition cost of the vaccine, and any additional staffing resources necessary for delivering the vaccine. A pilot vaccination program which tracked costs would aid in establishing more accurate cost data.

Conclusions

Vaccination of older adults against influenza in the ED setting appears to be cost-effective, especially for those over age 65 years. Our model's sensitivity to cost inputs highlights the need for prospective collection of cost and effectiveness data of administering a vaccination program. EDs offer a unique opportunity to provide influenza vaccination to a segment of society both underserved and at high risk for complications from influenza. This model,

which focused exclusively on the ED setting and was analyzed from a payer perspective, adds cost-effectiveness as an additional incentive for the adoption of vaccination strategies in EDs.

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References

1. Mullooly JP, Bridges CB, Thompson WW, Chen J, Weintraub E, Jackson LA, et al. Influenza- and RSV-associated hospitalizations among adults. *Vaccine*. 2007; 25(5):846–55. [PubMed: 17074423]
2. Beigel JH. Influenza. *Crit Care Med*. 2008; 36(9):2660–6. [PubMed: 18679129]
3. Dushoff J, Plotkin JB, Viboud C, Earn DJ, Simonsen L. Mortality due to influenza in the United States--an annualized regression approach using multiple-cause mortality data. *Am J Epidemiol*. 2006; 163(2):181–7. [PubMed: 16319291]
4. Molinari NA, Ortega-Sanchez IR, Messonnier ML, Thompson WW, Wortley PM, Weintraub E, et al. The annual impact of seasonal influenza in the US: measuring disease burden and costs. *Vaccine*. 2007; 25(27):5086–96. [PubMed: 17544181]
5. Rhodes KV, Gordon JA, Lowe RA. Preventive care in the emergency department, Part I: Clinical preventive services--are they relevant to emergency medicine? Society for Academic Emergency Medicine Public Health and Education Task Force Preventive Services Work Group. *Acad Emerg Med*. 2000; 7(9):1036–41. [PubMed: 11044001]
6. Babcock Irvin C, Wyer PC, Gerson LW. Preventive care in the emergency department, Part II: Clinical preventive services--an emergency medicine evidence-based review. Society for Academic Emergency Medicine Public Health and Education Task Force Preventive Services Work Group. *Acad Emerg Med*. 2000; 7(9):1042–54. [PubMed: 11044002]
7. Stiffler KA, Gerson LW. Health promotion and disease prevention in the emergency department. *Emerg Med Clin North Am*. 2006; 24(4):849–69. [PubMed: 16982343]
8. Fernandez WG, Oyama L, Mitchell P, Edwards EM, St George J, Donovan J, et al. Attitudes and practices regarding influenza vaccination among emergency department personnel. *J Emerg Med*. 2009; 36(2):201–6. [PubMed: 18281180]
9. Pallin DJ, Muennig PA, Emond JA, Kim S, Camargo CA Jr. Vaccination practices in U.S. emergency departments, 1992–2000. *Vaccine*. 2005; 23(8):1048–52. [PubMed: 15620478]
10. Jefferson T, Rivetti D, Rivetti A, Rudin M, Di Pietrantonj C, Demicheli V. Efficacy and effectiveness of influenza vaccines in elderly people: a systematic review. *Lancet*. 2005; 366(9492):1165–74. [PubMed: 16198765]
11. Rivetti D, Jefferson T, Thomas R, Rudin M, Rivetti A, Di Pietrantonj C, et al. Vaccines for preventing influenza in the elderly. *Cochrane Database Syst Rev*. 2006; 3 CD004876.
12. Nichol KL. Efficacy and effectiveness of influenza vaccination. *Vaccine*. 2008; 26(Suppl 4):D17–22. [PubMed: 19230153]
13. Fiore AE, Shay DK, Broder K, Iskander JK, Uyeki TM, Mootrey G, et al. Prevention and control of influenza: recommendations of the Advisory Committee on Immunization Practices (ACIP), 2008. *MMWR Recomm Rep*. 2008; 57(RR-7):1–60.
14. Rimple D, Weiss SJ, Brett M, Ernst AA. An emergency department-based vaccination program: overcoming the barriers for adults at high risk for vaccine-preventable diseases. *Acad Emerg Med*. 2006; 13(9):922–30. [PubMed: 16902048]

15. Wilber ST, Gerson LW, Terrell KM, Carpenter CR, Shah MN, Heard K, et al. Geriatric emergency medicine and the 2006 Institute of Medicine reports from the Committee on the Future of Emergency Care in the U.S. health system. *Acad Emerg Med*. 2006; 13(12):1345–51. [PubMed: 17071799]
16. Maciosek MV, Solberg LI, Coffield AB, Edwards NM, Goodman MJ. Influenza vaccination health impact and cost effectiveness among adults aged 50 to 64 and 65 and older. *Am J Prev Med*. 2006; 31(1):72–9. [PubMed: 16777545]
17. Nichol KL. The efficacy, effectiveness and cost-effectiveness of inactivated influenza virus vaccines. *Vaccine*. 2003; 21(16):1769–75. [PubMed: 12686092]
18. D’Heilly SJ, Blade MA, Nichol KL. Safety of influenza vaccinations administered in nontraditional settings. *Vaccine*. 2006; 24(18):4024–7. [PubMed: 16546307]
19. Lofgren E, Fefferman NH, Naumov YN, Gorski J, Naumova EN. Influenza seasonality: underlying causes and modeling theories. *J Virol*. 2007; 81(11):5429–36. [PubMed: 17182688]
20. Population Division of the United States Census Bureau. Table NC-EST2007-01: Annual Estimates of the Population by Sex and Five-Year Age Groups for the United States: April 1, 2000 to July 1, 2007. 2007 [5/1/2008]
21. Pitts SR, Niska RW, Xu J, Burt CW. National Hospital Ambulatory Medical Care Survey: 2006 emergency department summary. *Natl Health Stat Report*. 2008; 7:1–38.
22. Prosser LA, O’Brien MA, Molinari NA, Hohman KH, Nichol KL, Messonnier ML, et al. Non-traditional settings for influenza vaccination of adults: costs and cost effectiveness. *Pharmacoeconomics*. 2008; 26(2):163–78. [PubMed: 18198935]

Figure 1. Diagram of Markov states used in the model

Blue arrows represent transitions possible in all model strategies. In interventional strategies, patients seen in the ED have the additional option of being vaccinated in the ED, represented by the red arrow in the diagram. In the non-interventional arms, all patients seen in the ED move back to the unvaccinated state along the green transition.

Figure 2.

Cost-effectiveness acceptability curves for the intervention strategies. Above a WTP of roughly \$100 000 per life saved, vaccination for adults older than 65 years becomes the strategy most probable to be cost-effective.

Figure 3. Effects of changes in cost per life saved on the cost of influenza vaccination in ED setting. Below a cost of approximately 28.00, the intervention becomes cost saving for the older-than-65-years age group. Below \$25, it becomes cost saving for all adults older than 50 years.

Figure 4. Effect of Changes in the Influenza Incidence Rate on Incremental cost-Effectiveness
Emergency department influenza vaccination becomes more cost-effective strategy as attack rate increases over the base incidence. ICERs are calculated between each intervention strategy and next most expensive competing strategy.

Table 1

Values and sources for model costs

Parameter	Base cost	SD	Distribution	Reference
Anaphylactic reaction				
All groups	\$464	\$62.50	Normal	[19]
ED vaccination				
All groups	\$34.19	\$7.26	Normal	[19]
Influenza-related hospitalization, y				
>65, low risk	\$14 032	\$28 341	Log normal	[4]
>65, high risk	\$20 525	\$39 324	Log normal	[4]
50-65, low risk	\$27 331	\$117 303	Log normal	[4]
50-65, high risk	\$50 620	\$91 657	Log normal	[4]
Influenza-related death, y				
>65, low risk	\$51 403	\$118 210	Log normal	[4]
>65, high risk	\$40 452	\$75 857	Log normal	[4]
50-65, low risk	\$145 301	\$409 134	Log normal	[4]
50-65, high- risk	\$145 628	\$417 954	Log normal	[4]
Influenza-related outpatient visit, y				
>65, low risk	\$297	\$1,892	Log normal	[4]
>65, high risk	\$583	\$1,386	Log normal	[4]
50-65, low risk	\$184	\$939	Log normal	[4]
50-65, high risk	\$898	\$1,602	Log normal	[4]
Systemic reaction	Same as cost for outpatient visit for age/risk group	[19]		
Uncomplicated influenza				
All groups	\$4	\$2.45	Log normal	[4]
Vaccination at outside site				
All groups	\$29.73	\$5.19	Normal	[19]

Table 2

Values and sources for model probabilities

Parameter	Base probability/utility	SD	Distribution	Reference
Influenza attack rate (yearly), y				
>65	0.090 (cumulative)	$0.2 \times \text{weekly base}$	Normal	[4]
50-65	0.066 (cumulative)	$0.2 \times \text{weekly base}$	Normal	[4]
Outside vaccination rate, y				
>65	0.360 (cumulative)	NA	NA	[13]
50-65	0.660 (cumulative)	NA	NA	[13]
Probability of anaphylaxis reaction	2.95×10^{-5}	7.22×10^{-6}	Normal	[18]
Probability of influenza-related death, y				
>65	1.17×10^{-2}	3.9×10^{-3}	Log normal	[4]
50-65	1.34×10^{-3}	4.5×10^{-4}	Log normal	[4]
Probability of high-risk comorbidity				
>65	0.512	0.7	Log normal	[4]
50-65	0.33	0.73	Log normal	[4]
Probability of influenza-related hospitalization, y				
>65	4.21×10^{-2}	0.014	Log normal	[4]
50-65	1.93×10^{-2}	0.0064	Log normal	[4]
Probability of outpatient visit given flu, >65 y				
>65 y, low risk	0.62	0.027	Log normal	[4]
>65 y, high risk	0.82	0.093	Log normal	[4]
50-65 y, low risk	0.313	0.014	Log normal	[4]
50-65 y, high risk	0.625	0.118	Log normal	[4]
Probability of receiving vaccine in ED	0.807	0.1	Normal	[20]
Probability Pt. is >65 y	0.586	NA	NA	[21]
Probability Pt. is 50-64 y	0.414	NA	NA	[21]
Probability of systemic reaction with vaccination	4.98×10^{-5}	7.17×10^{-6}	Normal	[18]
Vaccine effectiveness (reduction in all end points), y				
>65	0.5	0.15	Normal	[12], [13], [19] and [22]
50-65	0.6	0.15	Normal	[12], [13] and [19]
Weekly probability of ED visit				
>65	1.06×10^{-2}	5.39×10^{-4}	Normal	[20]
50-65	7.18×10^{-3}	3.63×10^{-4}	Normal	[20]

Table 3

Base-case cost-effectiveness estimates for ED-based vaccination strategies

Intervention strategy	Cost (dollars per 100 000 persons)	Incremental cost (additional cost of strategy)	Deaths (per 100000)	Incremental effectiveness (lives saved per 100 000)	ICER
No vaccination offered	\$8 409 289	NA	39.9	NA	NA
Vaccination for patients >65 y vs no vaccination offered	\$8 426 664	\$17 375	38.6	1.33	\$13 084
Vaccination offered to all patients aged 50 y vs no vaccination offered	\$8 457 895	\$48 606	38.5	1.4	\$34 610
Vaccination offered to all patients aged 50 y vs vaccination for patients >65 y	\$8 457 895	\$31 231	38.5	0.08	\$408 784