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COST-EFFECTIVENESS OF A 10-YEAR REVACCINATION WITH TETANUS TOXOID, REDUCED DIPHTHERIA TOXOID, AND ACELLULAR PERTUSSIS (TDAP) VACCINE AMONG INDIVIDUALS WITH PRE-EXISTING ASTHMA IN THE UNITED STATES

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BACKGROUND

- A tetanus toxoid, reduced-antigen content diphtheria toxoid, and acellular pertussis vaccine (Tdap) was first licensed in the United States (US) in 2005[1].
  - The Centers for Disease Control and Prevention (CDC) currently recommends a single dose of Tdap for adolescents (aged 11 - 18 years) preferably at age 11, or for adults (aged >19 years) who did not yet receive a dose[2].
- Prior economic evaluations of Tdap have concluded that revaccination of adolescents and adults against pertussis (i.e., decennial Tdap booster) is not cost-effective at typical US willingness-to-pay thresholds unless assumptions of high pertussis disease incidence are included[3,4].
  - In particular, a recent CDC-developed model reported incremental cost-effectiveness ratios (ICERs) of $163,361 and $204,556 for Tdap revaccination at ages 16 or 21 years, respectively, following adjustment for underreporting of pertussis disease incidence[5].
- However, individuals with chronic respiratory conditions, such as asthma, are at increased risk for pertussis and experience an increased economic burden after pertussis diagnosis[6]. Individuals with pre-existing asthma may therefore benefit from targeted Tdap revaccination strategies.

Table 1. Model input variables

Model Parameter	Input	Source
Population		
Ages 21-30[a]	42,460,600	Calculated from US Census Bureau, 2012[8]
Life expectancy at birth	77.8 years	Miniño (2010)[9], 2008 value
Pertussis incidence in patients with pre-existing asthma		
Ages 11-20	38.577 per 100,000 PYs	Analysis of MarketScan Databases (2006-2014)
Ages 21-30	16.417 per 100,000 PYs	
Hospitalization rate in patients with pre-existing asthma		
Ages 11-20	11/477 = 2.31%	Analysis of MarketScan Databases (2006-2014)
Ages 21-30	1/57 = 1.75%	
Case fatality ratio per case		
Ages 11-15	0.011%	Kamiya et al. (2016)[5] citing NNDSS 2002-2011 data[10]
Ages 16-20	0.0043%	
Ages 21-30	0.0084%	
Unreported cases	0%	Assumption
Average duration of disease per pertussis case, days		
Ages 11-15	62	Kamiya et al. (2016)[5] citing EPS 2011-2012 (CDC unpublished)
Ages 16-20	52	
Ages 21-30	69	
Average length of hospitalization, days		
Ages 11-20	3.47	Kamiya et al. (2016)[5] citing Analysis of MarketScan databases (2003-2010)
Ages 21-30	2.93	
Utility values (disutility value)		
Outpatient case		
Ages 11-17	0.78 (0.22)	Lee et al. (2005)[3]; Rozenbaum et al. (2012)[11]
Ages 18+	0.85 (0.15)	
Hospitalized case		
Ages 11-17	0.67 (0.33)	Lee et al. (2005)[3]; Rozenbaum et al. (2012)[11]
Ages 18+	0.81 (0.19)	
Unreported case		
Ages 11-17	0.75 (0.253)	Liang (written communication, Oct 20, 2016); Rozenbaum et al. (2012)[11]
Ages 18+	0.84 (0.162)	
Vaccination parameters		
Initial vaccine effectiveness	74%	Kamiya et al. (2016)[5] citing Acosta et al. (2015)[12]
Annual reduction in vaccine effectiveness (waning per year)	15%	
Vaccine coverage		
Age 11 years	78%	Kamiya et al. (2016)[5]
Age 21 years	64%	
Direct medical costs (US$ 2016)		
Cost per hospitalized case in patients with pre-existing asthma		
Ages 11-20	$7,620	Analysis of MarketScan Databases (2006-2014)[b]
Ages 21-30	$15,678	
Cost per outpatient case in patients with pre-existing asthma		
Ages 11-20	$357	Analysis of MarketScan Databases (2006-2014)[b]
Ages 21-30	$277	
Vaccine acquisition cost (US$ 2017)		
Private price		
Boostrix	$37.55	Red Book (2017)[13], WAC
Td (*Tenivac*)	$32.89	
Boostrix	$39.35	CDC Vaccine Price List, 2017[14]
Td (generic)	$23.93	
Public price		
Boostrix	$24.36	CDC Vaccines Price List (2017)[14], contracted price
Td (generic)	$13.58	
Productivity loss costs		
Work days lost per case of pertussis		
Ages 11-17	0.47 days	Varan et al. (2016)[15]
Ages 18+	0.21 days	Calculated assuming 3 hours spent per outpatient visit, 6 work days per hospitalization (Luthy et al. 2015)[16]
Incremental work days lost for vaccination	0.0 days	Assumed equal for Tdap and Td vaccine
Hourly median wage (US$2016)	$17.81	BLS (2016b)[17]
Annual discount rate[c]	3%	Sanders et al. (2016)[18]

BLS: Bureau of Labor Statistics; CDC: Centers for Disease Control and Prevention; EPS: Enhanced Pertussis Surveillance; NNDSS: National Notifiable Diseases Surveillance System; PYs: person-years; Td: tetanus and diphtheria vaccine; Tdap: tetanus toxoid, reduced-antigen content diphtheria toxoid, and acellular pertussis vaccine; WAC: wholesale acquisition cost.

[a]Population data were provided in 5-year age groups and were assumed to be uniformly distributed across the 5-year age groups.

[b]Costs were inflated, where necessary, to 2016 US dollars using the medical care component of the consumer price index (BLS, 2016a)[19].

[c]Applied to costs and health outcomes.

Disclosures

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Trademarks

Boostrix is a trademark of the GSK group of companies.

Tenivac is a trademark of Sanofi Pasteur.

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Conflicts of interest

C Hogea and PO Buck are employed by the GSK group of companies and hold shares in the GSK group of companies. SE Talbird, J Meyers and J Carrico are employees of RTI-HS, which received payment from the GSK group of companies to conduct this research.

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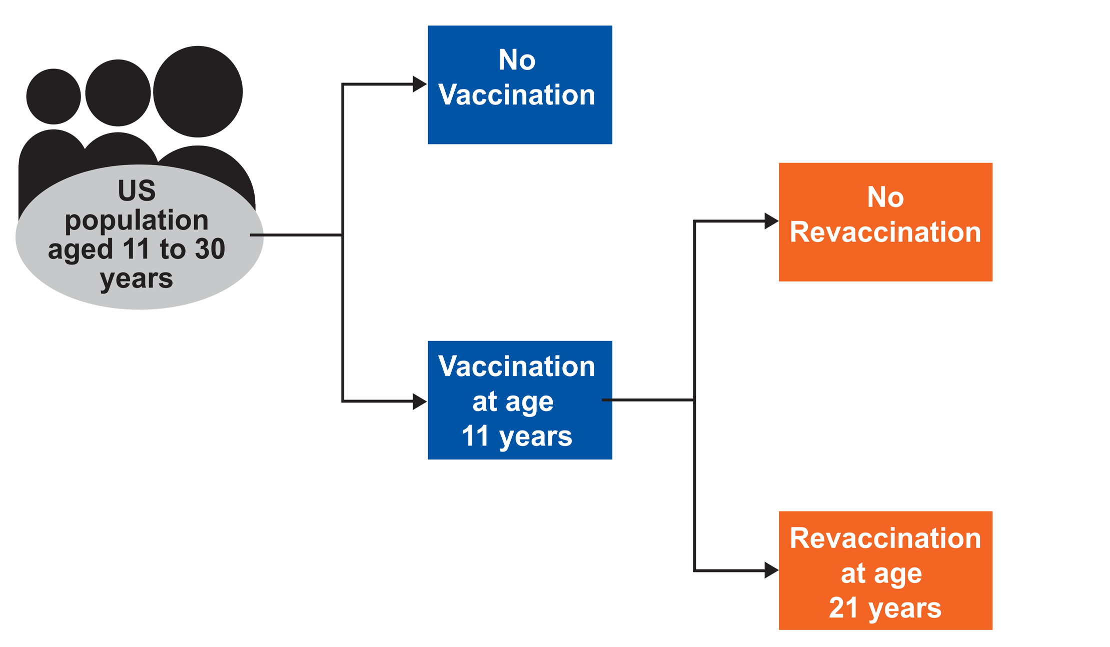
OBJECTIVE

- To conduct a cost-effectiveness analysis from the societal perspective of a one-time 10-year revaccination with Tdap to prevent pertussis among individuals with pre-existing asthma in the US.

METHODS

- A static, population-based model (**Figure 1**) was used to estimate the cost-effectiveness of Tdap revaccination at age 21 years compared with no revaccination for the prevention of pertussis (i.e. decennial booster with tetanus and diphtheria [Td] only) from the societal perspective.

Figure 1. Structure of the Population-Level[a] Cost-Effectiveness Analysis



[a]Because this is a population-level analysis over a 1-year time horizon (and not a cohort analysis), the current US population aged 11 years (3,214,380) and 21 years (2,800,384) are vaccinated.

- The analysis was conducted in the steady-state year (i.e., ~10 years after revaccination with Tdap was introduced at age 21), including quality-adjusted life years (QALYs) gained due to pertussis deaths avoided.
- The modeled population included individuals aged 21-30 years with pre-existing asthma.
- Model inputs, including vaccine effectiveness, utility decrements, and work days lost per pertussis case, were based on published literature (**Table 1**).
- Pertussis incidence, hospitalization rate, and cost of treatment for patients with pre-existing asthma were based on a retrospective analysis of a large nationwide US healthcare claims database (MarketScan databases) (**Table 1**).
  - Analyses were conducted using the ICD-9 codes for pertussis (033.0x, 033.9x, and 484.3x).
  - To account for improved disease recognition, scenario analyses included an adjustment factor for underreporting of pertussis ranging from 10 to 30.
- The model included only the incremental vaccine acquisition costs of Tdap (*Boostrix*) over the recommended decennial Td vaccine. Vaccine administration costs, travel costs, and productivity losses for vaccination were not included because they were assumed equal for the two vaccination strategies.
  - To account for various public and private prices for generic and branded Td vaccine, multi-way scenario analyses with several incremental vaccine acquisition costs (**Table 2**) were tested with and without each underreporting factor.
- ICERs were calculated comparing the two vaccination strategies. Results are shown in 2016/2017 US$.

Table 2. Incremental vaccine costs used in scenario analysis

	Pricing Scenario	Incremental vaccine cost (US$2017)
Base case	Average of private (Red Book)[13] and public prices[14]	$7.72
Price scenario 1	Average of private (CDC) and public prices[14]	$13.10
Price scenario 2	*Boostrix* minus *Tenivac* private prices[13]	$4.66
Price scenario 3	*Boostrix* minus Td generic, public prices[14]	$10.79
Price scenario 4	*Boostrix* minus Td generic, private prices[14]	$15.42

Td: tetanus and diptheria vaccine.

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RESULTS

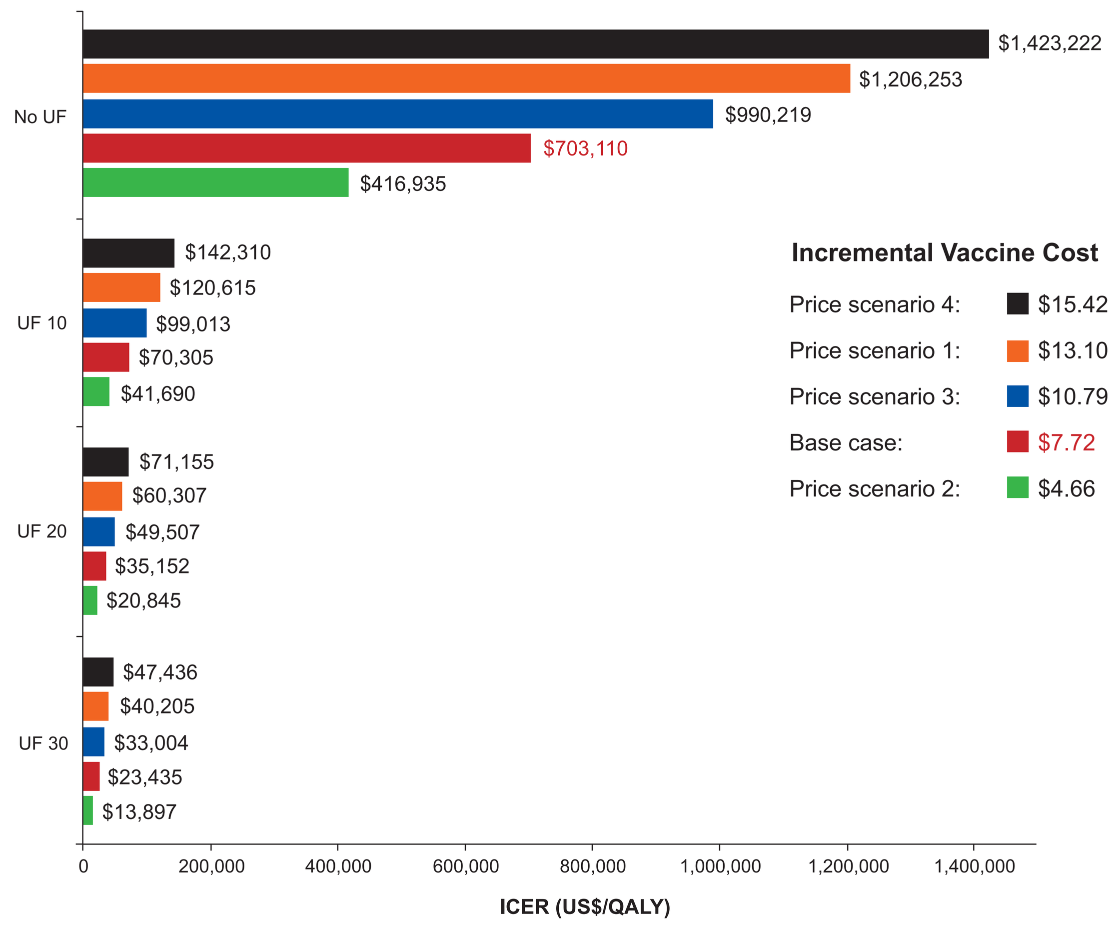
Base-case

- In the population with pre-existing asthma, vaccinating 11-year-olds followed by a 10-year Tdap revaccination resulted in an incremental cost of $21.05 million and 29.94 incremental QALYs gained compared with no revaccination for the prevention of pertussis.
- The QALYs gained resulted primarily from avoided outpatient cases (27.24 QALYs) and avoided deaths (2.21 QALYs).
- The base-case ICER of revaccination compared with no revaccination against pertussis was $703,110 per QALY gained (**Figure 2**).

Scenario Analyses

- When an underreporting factor of 10, 20, and 30 was applied to medically-attended pertussis incidence (from the MarketScan databases), the ICERs decreased to $70,305, $35,152, and $23,435 per QALY gained, respectively (**Figure 2**).
- In multi-way scenario analyses using an underreporting factor ranging from 10 to 30, the lowest incremental vaccine acquisition cost ($4.66) resulted in an ICER ranging from $13,897 to $41,690, respectively; the highest incremental vaccine acquisition cost ($15.42) resulted in an ICER ranging from $47,436 to $142,310, respectively (**Figure 2**).

Figure 2. ICERs from base-case and multi-way scenario analysis testing the impact of various incremental vaccine costs and underreporting factors



ICER, incremental cost-effectiveness ratio; UF, underreporting factors; QALY, quality-adjusted life year.

LIMITATIONS

- Adverse events from vaccination were not included in the analysis.
- Results of the analysis reflect the cost-effectiveness in the steady-state year, which would likely occur ~10 years after decennial revaccination with Tdap at age 21 were implemented in the US.

CONCLUSIONS

- **Results were highly sensitive to the incremental cost of Tdap compared with Td vaccine and the underreporting factor of pertussis incidence.**
  - **The incremental cost of Tdap compared with Td vaccine will vary by provider or health plan such that there is not one representative incremental cost among those considering revaccination in the US.**
  - **While pertussis incidence in children with pre-existing asthma is likely to be accurate, underreporting among adolescent and adults is known to occur[7].**
- **A one-time 10-year revaccination strategy with Tdap may be cost-effective among certain high-risk populations, including individuals with pre-existing asthma, who are at higher risk of pertussis and experience an increased economic burden.**
  - **The extent to which revaccination with Tdap is cost-effective at typical US willingness-to-pay thresholds for this population depends on the true level of underreporting in this population.**

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