Value of Pediatric Vaccinations: An Economic Evaluation of the Pediatric Vaccination Schedule in the United States

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BACKGROUND

- The introduction and widespread use of pediatric vaccines has resulted in dramatic declines in the morbidity, disability, and mortality caused by infectious diseases[1]
- Zhou et al. examined the economic impact of the 2001 pediatric vaccination schedule [diphtheria, tetanus, pertussis (DTaP); haemophilus influenzae type b (Hib); poliovirus (Polio); measles, mumps, rubella (MMR); hepatitis B (HepB); and varicella]. Vaccinating a birth cohort according to the schedule was estimated to save nearly $10 billion in direct medical costs[2]
- The 2010 vaccination schedule includes additional vaccines: including adolescent meningococcal, rotavirus, HPV, influenza, and hepatitis A[3]

OBJECTIVE

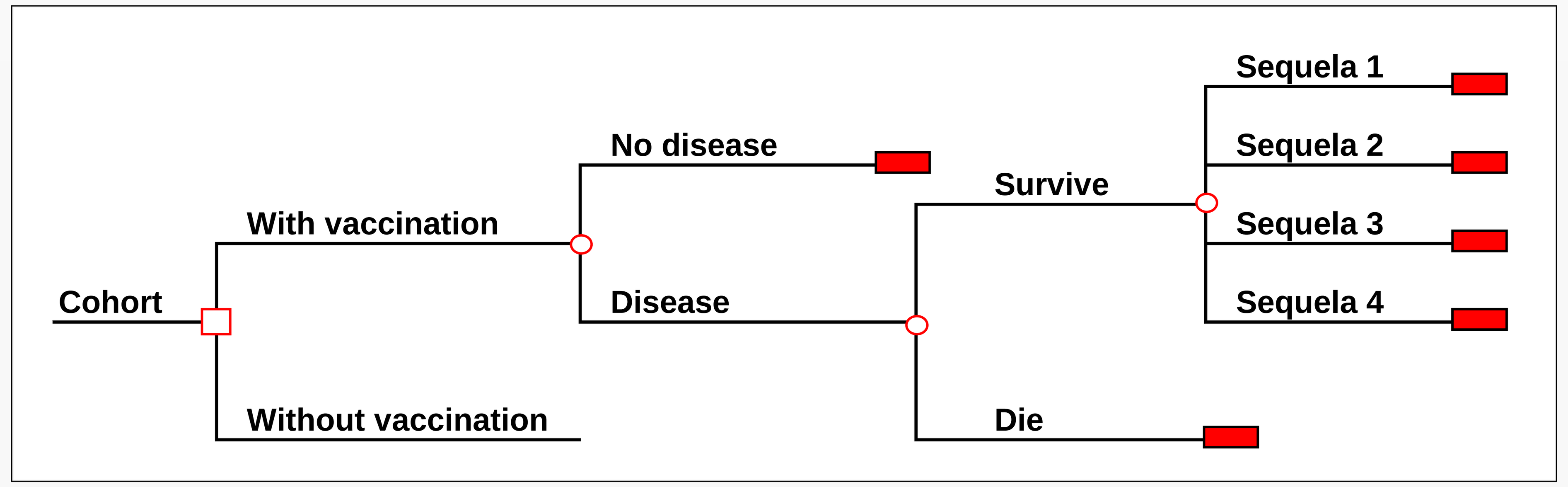
- Update the 2001 analysis by using the current vaccination schedule to understand the costs of the vaccination program relative to the costs and quality adjusted life years (QALYs) saved by preventing the covered diseases.

METHODS

Modeling approach:

- An economic analysis was conducted to combine estimates of vaccine-specific costs (vaccine and direct medical costs) and outcomes (QALYs) compared with no vaccination.
- Vaccine-specific estimates were obtained from the literature for:
  - •Vaccine costs
  - •Incremental direct medical costs per vaccinated person
  - •QALYs gained per vaccinated person
- Estimates were obtained from studies that:
  - •Evaluated the direct effect of vaccination compared with no vaccination, using a birth cohort approach
  - •Discounted costs and outcomes by 3%
- QALY estimates not available from the literature were calculated using a decision tree model (Figure 1)

Figure 1: Decision tree model



METHODS (continued)

- Per-person cost and QALY estimates were applied to the number vaccinated in the 2008 birth cohort
- Vaccine-specific estimates were combined to evaluate the cost-effectiveness of the schedule as a whole

Vaccine strategies:

- DTaP, Polio, Hib, HepB, MMR, other single disease vaccines
- DTaP + Polio + Hib (Pentacel), Hep B, MMR, other single disease vaccines
- DTaP + Polio + Hep B (Pediarix), Hib, MMR, other single disease vaccines

Estimation:

- Vaccine costs were obtained from CDC vaccine price list;[4] administration costs were obtained from Physician Fee and Coding Guide[5] and state-specific Medicaid reimbursement rates[6]
- Vaccine coverage was obtained from the National Immunization Survey[7]

Incremental costs per person vaccinated (Table 1) were calculated as:

$$\Delta DM_{pp} = (\Delta DM_{agg} / (N \times V_{cov}))$$

Where: ΔDM_{pp} = Direct medical cost per person vaccinated
ΔDM_{agg} = Aggregate direct medical costs
N = Number in birth cohort
V_{cov} = Vaccine coverage

Aggregate incremental costs and QALYs were calculated as:

$$\Delta C = (\Delta DM_{pp} \times N \times V_{cov}) + (V_{cost} \times D \times N \times V_{cov})$$

Where: ΔC = Incremental costs
V_{cost} = Vaccine cost
D = Number of doses

- Incremental QALYs per person vaccinated were similarly calculated (Table 1)
- Incremental costs (2009 USD, discounted 3%) represent the costs incurred by a vaccinated cohort compared with an unvaccinated cohort, over their lifetime

Table 1: Calculation of incremental costs and QALYs per person vaccinated

Disease	Birth Cohort (N)	Coverage	Aggregate DM Cost Savings ($2009)	DM Cost Savings ($2009) per vaccinated person	Aggregate Incremental QALYs	Incremental QALYs per vaccinated person
Diphtheria (3+ doses)	3,803,295	94%	$3,246,684,216	$907	566,629	0.1583
Tetanus (3+ doses)	3,803,295	94%	$11,015,044	$3	985	0.0003
Pertussis (3+ doses)	3,803,295	94%	$3,019,498,933	$844	120,650	0.0337
Measles (1+ dose)	3,803,295	91%	$3,641,848,919	$1,058	193,013	0.0561
Mumps (1+ dose)	3,803,295	91%	$1,286,006,386	$374	6,698	0.0019
Rubella (1+ dose)	3,803,295	91%	$155,140,377	$45	142,862	0.0415
Polio (3+ doses)	3,803,295	90%	$2,869,418,959	$843	128,626	0.0378
Hib (3+ doses)	3,815,469	93%	$1,952,931,240	$548	113,644	0.0319
Hepatitis B (3 doses)	3,803,295	90%	$205,155,194	$60	1,565	0.0005
Hepatitis A (2 doses)	4,021,726	87%	$45,162,591	$13	2,154	0.0006
Varicella (1+ dose)	4,100,000	95%	$362,988,292	$93	15,804	0.0041
Influenza: age 0-4 (1 dose)	4,000,608	HR*:62% LR**: 39%	$643,346,371	$259 $412	51,280	0.0207 0.0329
Influenza: age 5-17 (1 dose)	4,000,608	HR*:36% LR**: 21%	$400,012,706	$278 $476	31,086	0.0216 0.0370
Pneumococcal	3,800,000	100%	$549,169,902	$145	3,294	0.0009
Rotavirus (1+ dose)	4,010,000	70%	$248,793,648	$89	347	0.0001
HPV (3 doses)	1,988,614	100%	$958,511,948	$482	1,591	0.0008
Meningococcal (adolescents) (1 dose)	4,238,672	71%	$22,867,496	$8	1,805	0.0006

*High risk of complication; ** low risk of complication

Data sources: Diphtheria, tetanus, pertussis, measles, mumps, rubella, Polio, hib, hepB – costs, Zhou 2005[2] , QALYs, decision tree model; hepA-costs and QALYs, Rein 2007[8]; varicella-costs and QALYs, Zhou 2008[9]; Prosser 2006[10]; pneumococcal-costs , Lieu 2000[11], QALYs, decision tree model; rotavirus-costs, Widdowson 2007[12], QALYs, decision tree model; HPV-costs and QALYs, Cervarix cost-effectiveness model[13]; meningococcal-costs and QALYs, Shepard 2005[14]

RESULTS

Table 2: Incremental costs and QALYs per vaccination schedule

Incremental costs* ($US in billions), [QALYs Gained (in Thousands)]						
Vaccine	DTaP, MMR, polio, Hib, HepB, single disease vaccines*		Pentacel, (DTaP, polio, Hib) , MMR, Hep B, single disease vaccines		Pediarix (DTaP, polio, Hep B), MMR, Hib, single disease vaccines	
	Δ Costs	Δ QALYs	Δ Costs	Δ QALYs	Δ Costs	Δ QALYs
DTaP	-$6.462	[798]	/	/	/	/
MMR	-$5.374	[386]	-$5.374	[386]	-$5.374	[386]
Polio	-$2.805	[151]	/	/	/	/
Hib (infants)	-$1.447	[115]	/	/	-$1.447	[115]
Hep B	0.177	[1.816]	$0.177	[1.816]	/	/
Hep A	$0.123	[1.237]	$0.123	[1.237]	$0.123	[1.237]
Varicella	0.288	[15.7]	$0.288	[15.7]	$0.288	[15.7]
Influenza	$0.194	[36.3]	$0.194	[36.3]	$0.194	[36.3]
Pneumococcal	$0.996	[3.32]	$0.996	[3.32]	$0.996	[3.32]
Rotavirus**	$0.302	[0.220]	$0.302	[0.220]	$0.302	[0.220]
HPV†	-$0.0446	[0.511]	-$0.0446	[0.511]	-$0.0446	[0.511]
Mening (adolescent)	$0.170	[0.984]	$0.170	[0.984]	$0.170	[0.984]
Pentacel	/	/	-$11.49	[1088]	/	/
Pediarix	/	/	/	/	-$9.67	[957]
Cost Savings (billions)	$13.88		$14.66		$14.46	
QALYs gained (millions)	1.51		1.53		1.52	
Benefit / Cost Ratio	3.12:1		3.36:1		3.36:1	

Schedule completed with DTaP, MMR, single disease vaccines (HPV vaccine is Gardasil ®, Rotavirus vaccine is RotaTeq®0 . Alternative base c ase results are: 13.74 billions in savings with Rotarix ®, -13.71 billions in savings with Cervarix ®
* Calculated as the cost of vaccine minus the costs of cases; **RotaTeq estimates used, Rotarix ICER is estimated as $1,148,723 per QALY gained. Results differ from previous analysis[12] due to differences in discounting of outcomes.
†Gardasil estimates used, Cervarix is also estimated as cost-saving

- The current vaccine schedule saves nearly $14 billion over the lifetime of the 2008 US birth cohort
- DTaP, MMR, Polio, Hib, HPV and multivalent vaccines are cost-saving
- Strategies that included multivalent vaccines provide increased cost savings due to lower administration costs

CONCLUSIONS

- The current pediatric vaccine schedule is cost saving and provides substantial benefits in terms of QALYs
- Pentavalent vaccines result in greater savings than single-disease vaccines

REFERENCES

[1] Roush SW, Murphy TV and the Vaccine-Preventable Disease Table Working Group. Historical Comparisons of Morbidity and Mortality for Vaccine-Preventable Diseases in the United States. JAMA 2007;298(18):2155-2163.; [2] Zhou F, Santoli J, Messonier ML, et al. Economic evaluation of the 7-vaccine routine childhood immunization schedule in the United States, 2001. Arch Pediatr Adolesc Med 2005:159:1136-1144.; [3] Centers for Disease Control and Prevention. CDC Vaccine Price List. Available at http://www.cdc.gov/vaccines/programs/vfc/cdc-vac-price-list.htm. Accessed January 15, 2010.; [4] Centers for Disease Control and Prevention. CDC Vaccine Price List. Available at http://www.cdc.gov/vaccines/programs/vfc/cdc-vac-price-list.htm. Accessed January 15, 2010.; [5] Physician's Fee and Coding Guide, Volume 1. Duluth, GA: MAG Mutual Healthcare Solutions, Inc; 2007.; [6] Medicaid Reimbursement State Reports 2004/5. American Academy of Pediatrics. Available at: http://www.aap.org/research/medreim0405state.htm; [7] National immunization survey; [8] Rein DB, Hicks KA, Wirth KE. Cost-Effectiveness of Routine Childhood Vaccination for Hepatitis A in the United States Pediatrics 2007;119:e12-e21.; [9] Zhou F, Ortega-Sanchez IR, Guris D et al. An economic analysis of the universal varicella vaccination program in the United States. The Journal of Infectious Diseases 2008; 197:S156–64.; [10] Prosser LA, Bridges CB, Uyeki M, et al. Health Benefits, risks, and cost-effectiveness of influenza vaccination of children. Emerging Infec Dis 2006;12(10):1548-1558.; [11] Lieu TA, Ray GT, Black SB, Butler JC, Klein JO, Breiman RF, Miller MA, Shinefield HR. Projected cost-effectiveness of pneumococcal conjugate vaccination of healthy infants and young children. JAMA 2000;283:1460-8.; [12] Widdowson M. Meltzer MI, Zhang X., et al. Cost-effectiveness and Potential Impact of Rotavirus Vaccination in the United States. Pediatrics 2007;119:684-697.; [13] i3 Innovus Cervarix model; [14] Shepard CW, Ortega-Sanchez R, Scott D. et al. Cost-effectiveness of conjugate meningococcal vaccination strategies in the United States. Pediatrics 2005;115:1220-1232.

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