Cost-effectiveness of HPV vaccination in the U.S.

A review of published and ongoing cost-effectiveness models focusing on age at vaccination

Harrell Chesson, PhD

NCHHSTP, CDC

February 2008

Background

- Several published and ongoing modeling efforts of HPV vaccine cost-effectiveness
- Previous cost-effectiveness presentations to ACIP
  - February 2006
  - June 2006
  - October 2006
- New cost-effectiveness estimates available
  - Age at vaccination
  - Inclusion of other vaccine benefits:
    - Cross-protection against other high-risk HPV types
    - Prevention of cancers other than cervical
    - Prevention of recurrent respiratory papillomatosis (RRP)

Outline

- Vaccine benefits included in cost-effectiveness estimates in this review
- Summary of cost effectiveness estimates
  - Routine vaccination of 12-year-old girls
  - Vaccination of older females

Health outcomes included in cost-effectiveness estimates in this review

- CIN 1-3
- Cervical cancer
- Genital warts
  - quadrivalent vaccine only

All modeling efforts in this review examine the cost-effectiveness of adding HPV vaccination of females to an existing cervical cancer screening program

CIN: cervical intraepithelial neoplasia

Vaccine benefits excluded
(except where noted)

- Prevention of cancers other than cervical
    - Anal, vaginal, vulvar, oropharyngeal, etc.
- Prevention of recurrent respiratory papillomatosis (RRP)
- Cross-protection
  - Protection against high-risk HPV types other than 16,18

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HPV vaccination of 12-year-old girls

Summary of published U.S. studies

Study	Vaccine cost per series	Cost per QALY gained	
		Vaccine protects against HPV 16/18	Vaccine protects against 6/11/16/18
Sanders & Taira, 2003 (2001 $US)	$300 + $100 booster	**$22,800**	-
Goldie et al., 2004 (2002 $US)	$377	**$24,300**	-
Taira et al., 2004 (2001 $US)	$300 + $100 booster	**$14,600***	-
Elbasha et al., 2007 (2005 $US)	$360	**$21,400**	**$3,000***
	$360	**$10,200*#**	-
Chesson et al., 2008 (2005 $US)	$360	**$14,700**	**$10,300**
	$360	**$10,300***	**$5,300***

***Indicates indirect effects (herd immunity) included

All studies (1) assumed lifelong vaccine protection, except those noting cost of booster shot, and (2) examined the addition of HPV vaccination to current cervical cancer screening.

Not reported in published study. Based on unpublished results from modified version of published model.

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HPV vaccination of 12-year-old girls: Summary

- Cost-effective by usual standards
- $3,000 to $24,000 per QALY gained
  - More cost-effective when including:
    - Protection against HPV 6/11
    - Indirect effects (herd immunity)
- Consistent results across range of different models

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Cost-effectiveness of HPV vaccination of older females

- Only one published study for US beyond age 15 years
  - Elbasha et al., 2007 (Merck)

- Vaccinating females 12-24 years old would cost $4,700 per QALY gained
  - Compared to vaccinating 12-year-old girls only
  - Quadrivalent vaccine, lifetime duration of protection, including indirect effects

Cost-effectiveness of HPV vaccination of older females: ongoing modeling efforts

- Merck model
  - based on Elbasha et al., 2007
- Spreadsheet model
  - based on Chesson et al., 2008
- Goldie/Kim model
  - Goldie, Kim, et al.
  - Funded in part by CDC

Merck model: Selected assumptions

- Type of model: dynamic transmission model
- Vaccine cost: $360 per series
- Duration of vaccine protection: lifelong
- Vaccine efficacy with 3 doses:
  - 90% against infection with HPV 6/11/16/18
  - 95.2% against CIN
  - 98.9% against genital warts
- Vaccine efficacy with < 3 doses: 0%
- Cervical cytology screening (% per year) by age:
  - 15-19: 21% 20-24: 45% 25-29: 62%
  - 30-34: 55% 35-54: ≈ 50% 55-64: ≈ 44%
  - 65-69: 39% 70-74: 30% 75-79: 20%
  - 80-84: 11% 85+: 6%

Merck model: Assumptions, continued

- Annual penetration rates* with 3 doses of vaccine, accounting for compliance:
  - <12 years: 39%
    - Increases linearly to 39% over the first five years of vaccination
  - 12-19 years: 20%
  - 20-29 years: 11%
  - 30-44 years: 3%
- Compliance:
  - 75% of those receiving 1st dose received 2nd dose
  - 75% of those receiving 2nd dose received 3rd dose
- Health outcomes included:
  - CIN, cervical cancer, genital warts
    - Including prevention of genital warts in males as a result of female vaccination

*Penetration rate: annual rate of vaccination among those not previously vaccinated

Cost-effectiveness of vaccination by age groups: Merck model results

Ages vaccinated	Cost per QALY
No vaccination	-
12-24	$8,600
12-29	$46,400
12-34	$103,600
12-39	$156,400
12-44	$225,300

The cost per QALY (quality-adjusted life year) of each given strategy is the incremental cost-effectiveness ratio of the given strategy when compared to the preceding strategy. All strategies include cervical cancer screening.

Preliminary

Spreadsheet model: Selected assumptions

- Incidence-based cohort model
  - Estimates potential benefit of HPV vaccination based on current burden of HPV-related disease
- Vaccine cost: $360 per series
- Duration of vaccine protection: Lifelong
- Vaccine efficacy: 100%

Spreadsheet model: Assumptions, continued

- No type-specific benefit to persons exposed to HPV vaccine type prior to vaccination
  - HPV type-specific incidence based on previous HPV models, placebo arms of vaccine trials
- Excludes indirect effects (herd immunity)
- Health outcomes included:
  - CIN, cervical cancer, genital warts

Cost-effectiveness of vaccination by age: Spreadsheet model results

Ages vaccinated	Cost per QALY gained
No vaccination	-
12	$8,600
12-18	$10,900
12-21	$31,800
12-24	$60,900
12-26	$92,300
12-29	$141,700
12-34	$226,100

Excludes indirect effects

The cost per QALY (quality-adjusted life year) of each given strategy is the incremental cost-effectiveness ratio of the given strategy when compared to the preceding strategy. All strategies include cervical cancer screening.

Preliminary

Goldie/Kim model: Selected assumptions

- Type of model:
  - Dynamic model and individual-based model
- Vaccine cost: $500 per series
  - $360 price for 3 doses
  - plus office visit and administration, and patient time
- Duration of vaccine protection: lifelong
- Vaccine efficacy: 100%
  - among those without prior history of type-specific infection

Goldie/Kim model: Assumptions, continued

- Coverage:
  - Routine vaccination pre-adolescents: 25% (year 1), 75% (year 5)
  - Older ages: 25% per year
- Cervical cancer screening:
  - conventional and liquid-based cytology
    - 53% annual,
    - 17% biennial,
    - 11% triennial,
    - 15% five-year,
    - 5% never screened;
- Health outcomes included:
  - CIN, cervical cancer
  - Warts, juvenile-onset RRP

RRP: recurrent respiratory papillomatosis

Cost-effectiveness of vaccination by age groups: Goldie/Kim model

Ages vaccinated	Cost per QALY gained (CIN, cervical cancer)	Cost per QALY gained (CIN, cervical cancer, + warts, RRP)
No vaccination	-	-
11-12	< $50,000	< $40,000
11-18	< $100,000	< $90,000
11-21	> $110,000	> $100,000
11-26	> $150,000	> $125,000

Preliminary

RRP: recurrent respiratory papillomatosis

The cost per QALY (quality-adjusted life year) of each given strategy is the incremental cost-effectiveness ratio of the given strategy when compared to the preceding strategy. All strategies include cervical cancer screening.

Summary: Incremental cost per QALY gained by vaccinating older age groups (quadrivalent vaccine)

Cutoff age for vaccination	Merck model	Spreadsheet model	Goldie/Kim model (including RRP)
18		$10,900	< $90,000
21		$31,800	> $100,000
24	$8,600	$60,900	
26		$92,300	> $125,000
29	$46,400	$141,700	
34	$103,600	$226,100	
39	$156,400		
44	$225,300		

Results are preliminary. The cost-effectiveness (CE) ratio for expanding vaccination to a given cutoff age shows the incremental cost per QALY gained compared to the nearest cutoff age above for which a CE ratio is provided. For example, the incremental cost-effectiveness ratio associated with increasing the cutoff age of vaccination from 24 to 29 is $46,400 in the Merck model. For the Merck model, the $8,600 estimate for age 24 is compared to no vaccination. For the spreadsheet model and Harvard model, the CE ratios for age 18 are as compared to vaccination of 11-12 year olds only.

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44	$225,300		

Includes prevention of genital warts in males as a result of vaccination of females

$500 per vaccine series ($360 in other models)

Conclusion

- Routine HPV vaccination of 12-year-old girls cost-effective by usual standards
  - Generally consistent results across models
- Vaccination less cost-effective as age at vaccination increases
  - Age at which vaccine no longer “cost-effective” is ambiguous
  - Wide range of results across different models
    - Reasons unclear at this time
      - Uncertainty of natural history of HPV
      - Different modeling assumptions, methods

Next steps

- Ongoing modeling of cost-effectiveness of vaccination by age
  - Understand differences in models, results
  - Determine most plausible ranges for cost-effectiveness estimates by age
- Continue to examine impact of including other vaccine benefits on vaccine cost-effectiveness:
  - Cross protection, RRP, other cancers

Acknowledgements

Lauri Markowitz
Eileen Dunne
Mona Saraiya
Donatus Ekwueme

Preliminary results provided by:

Merck: Elamin Elbasha, Erik Dasbach, Ralph Insinga, Richard Haupt

Harvard: Sue Goldie, Jane Kim

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