

Universal Tool for Vaccine Scheduling: Applications for Children, Adolescents, and Adults

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2014 Recommended Immunizations for Children from Birth Through 6 Years Old



Approved by the Advisory Committee on Immunization Practices (http://www.cdc.gov/vaccines/recs/acip), the American Academy of Pediatrics (http://www.aap.org), and the American Academy of Family Physicians (http://www.aafp.org).

http://www.cdc.gov/vaccines/parents/downloads/parent-ver-sch-0-6yrs.pdf

Publicly funded Immunization Programs in Canada - Routine Schedule for Infants and Children (including special programs and catch-up programs)

Province/ Territory	DTaP -IPV- Hib	DTaP -IPV	Td, Tdap or Td-IPV	НВ	MMR	Var	MMRV	Men-C	Men-C-A, C, Y, W- 135	Pneu -C-7	Pneu -C- 10	Pneu-C- 13	Inf	HPV	Rot
NACI recom- mendation	2, 4, 6, 18 mths	4-6 yrs	14-16 yrs	Infancy (3 doses) OR Pre- teen/teen (2-3 doses)	12 mths AND 18 mths OR 4-6 yrs	12-18 mths (1 dose)	12 mths AND 18 mths OR 4-6 yrs	Infancy (1- 4 doses) ¹ AND Pre- teen (1 dose) ¹	Pre-teen (1 dose) ¹	2, 4, 6, 12 -15 mths	2, 4, 6, 12 -15 mths	2, 4, 6, 12-15 mths	6-23 mths (1 -2 doses)	Females 9-13 yrs (3 doses at 0, 2, 6 mths) 2	2, 4, 6 mths
BC	2, 4, 6 (DTaP - HB- IPV- Hib); 18 mths (DTaP -IPV- Hib)	4-6 yrs	Tdap, Gr. 9	2, 4, 6 mths (DTaP- HB-IPV- Hib); Catch-up Gr. 6 (HB)	12, 18 mths	12 mths, Catch-up 4-6 yrs, Gr. 6		2, 12 mths; Gr. 6				2, 4, (6 HR), 12 mths	6-23 mths	Females Gr. 6, 9	
АВ	2, 4, 6, 18 mths	4-6 yrs	Tdap, Gr. 9	Gr. 5	12 mths, 4-6 yrs	12 mths		2, 4, 12 mths		2, 4, 6, 18 mths			6-59 mths	Females Gr. 5; Catch- up Gr. 9 in 2009- 12	

Province/territory specific recommendations were collected by the Canadian Nursing Coalition on Immunization (CNCI).

http://www.phac-aspc.gc.ca/im/ptimprog-progimpt/table-1-eng.php

Statistics reported by Luman et al. 2002¹ following the 2000 National Immunization Survey (NIS):

- Only 9% of children received all recommended vaccines at the recommended ages.
- 55% of children did not receive all recommended doses by 2 years of age.
- 8% of children received at least 1 vaccination dose too early to be considered valid.

¹ Luman, E.T., M.M. McCauley, S. Stokley, S.Y. Chu, L.K. Pickering. 2002. Timeliness of Childhood Immunizations. *American Journal of Preventive Medicine* **110**.

Problem Description: Untimely Vaccination

Statistics reported following the 2008 NIS:

For children 19-35 months old ²:

- National coverage rates for the vaccines routinely recommended for children 19-35 months old were reported at 76.1%
- Coverage among states varied from 59.2% to 82.3%.
- Coverage rates for the Hepatitis B birth dose ranged from 19.2% to 81.4% between states.

For adolescents aged 13-17 years ³:

- Coverage rates for Tdap, MCV, and at least one dose of HPV were reported at 40.8%, 41.8%, and 37.2%, respectively.
- Only three states had coverage over 50% for all three vaccines routinely recommended for adolescents.

² CDC. 2009. National, state, and local area vaccination coverage among children aged 19-35 months – United States, 2008. *Morbidity and Mortality Weekly Report* **58** 921-926.

³ CDC. 2009. National, state, and local area vaccination coverage among adolescents aged 13-17 years– United States, 2008. *Morbidity and Mortality Weekly Report* **58** 997-1001.

Problem Description: Causes of Untimely Vaccination

Reasons often cited for incorrect and untimely vaccination:

- parental negligence and misinformation
- incomplete or incorrect schedules constructed by health professionals due to:
 - insufficient knowledge and addition of new vaccines to the lineup, ^{4, 5}
 - problem complexity and tedious process of manual construction.

⁴ LaRussa, P., S. Chen, P. Sternfels, L. Cooper, A. Caesar, M. Ewing, M. Irigoyen, S. Findley. Impact of immunization schedule changes on missed opportunities for vaccination. The 37th National Immunization Conference, Chicago, IL, 2003.

⁵ Cohen, N.J., D.S. Lauderdale, P.B. Shete, J.B. Seal, R.S. Daum. 2003. Physician knowledge of catch-up regimens and contraindications for childhood immunizations. *Pediatrics* **111** 925-932.

FIGURE 2. Catch-up immunization schedule for persons aged 4 months through 18 years who start late or who are more than 1 month behind -United States, 2014.

The figure below provides catch-up schedules and minimum intervals between doses for children whose vaccinations have been delayed. A vaccine series does not need to be restarted, regardless of the time that has elapsed between doses. Use the section appropriate for the child's age. Always use this table in conjunction with Figure 1 and the footnotes that follow.

			Persons aged 4 months through 8 years		
Varcine	Minimum		Minimum Interval Between Doses		
vacche	Dose 1	Dose 1 to dose 2	Dose 2 to dose 3	Dose 3 to dose 4	Dose 4 to dose 5
Hepattis B ^r	Birth	4 weeks	8 weeks and at least 16 weeks after first dose; minimum age for the final dose is 24 weeks		
Rotavirus ²	6 weeks	4 weeks	4 weeks ²		
Diphtheria, tetanus, & acellular pertussis ³	6 weeks	4 weeks	4 weeks	6 months	6 months ¹
Haemophilus Influenzae type b ^s	6 weeks	4 weeks if first dose administered at younger than age 12 months 8 weeks (as final dose) If first dose administered at age 12 through 14 months No further doses needed If first dose administered at age 15 months or older	4 weeks ⁶ if current age is younger than 12 months and first dose administered at < 7 months old 8 weeks and age 12 months through 59 months (as final dose) ⁶ if current age is younger than 12 months and first dose administered between 7 through 11 months (regardless of Hib vaccine [PRP-to F RRP-OMP] used for first dose); <u>OB</u> If current age is 12 through 59 months and first dose administered at younger than age 12 months; <u>OB</u> first 2 doses were PRP-OMP and administered at younger than 12 months. No further doses needed if previous dose administered at age 15 months or older	8 weeks (as final dose) This dose only necessary for children aged 12 through 59 months who received 3 (PRP-T) doses before age 12 months and started the primary series before age 7 months	
Pneumococcal ⁶	6 weeks	4 weeks if first dose administered at younger than age 12 months 8 weeks (as final dose for healthy children) if first dose administered at age 12 months or older No further doses needed for healthy children if first dose administered at age 24 months or older	4 weeks if current age is younger than 12 months 8 weeks (as final dose for healthy children) if current age is 12 months or older No further doses needed for healthy children if previous dose administered at age 24 months or older	8 weeks (as final dose) This dose only necessary for children aged 12 through 59 months who received 3 doses before age 12 months or for children at high risk who received 3 doses at any age	
inactivated poliovirus7	6 weeks	4 weeks ⁷	4 weeks ⁷	6 months ⁷ minimum age 4 years for final dose	
Meningococcal®	6 weeks	8 weeks ^{t0}	See footnote 13	See footnote 13	
Measles, mumps, rubella ⁹	12 months	4 weeks			(
Varicella ¹⁰	12 months	3 months			
Hepatitis A [#]	12 months	6 months		RE	BOOK
			Persons aged 7 through 18 years		DOOR
				The second s	

http://www.cdc.gov/vaccines/schedules/downloads/child/0-18yrs-child-combined-schedule.pdf

Catch-up Scheduling for Childhood immunization

Problem Description: Causes of Untimely Vaccination

Reasons often cited for incorrect and untimely vaccination:

- parental negligence and misinformation
- incomplete or incorrect schedules constructed by health professionals due to:
 - insufficient knowledge and addition of new vaccines to the lineup, ^{4, 5}
 - problem complexity and tedious process of manual construction.
- missed opportunities for vaccination ⁶
- environmental and socioeconomic standings.
- ⁴ LaRussa, P., S. Chen, P. Sternfels, L. Cooper, A. Caesar, M. Ewing, M. Irigoyen, S. Findley. Impact of immunization schedule changes on missed opportunities for vaccination. The 37th National Immunization Conference, Chicago, IL, 2003.
- ⁵ Cohen, N.J., D.S. Lauderdale, P.B. Shete, J.B. Seal, R.S. Daum. 2003. Physician knowledge of catch-up regimens and contraindications for childhood immunizations. *Pediatrics* **111** 925-932.
- ⁶ Szilagyi, P.G., L.E. Rodewald, S.G. Humiston, R.F. Raubertas, L.A. Cove, C.B. Doane, P.H. Lind, M.S. Tobin, K.L. Roghmann, C.B. Hall. 1993. Missed opportunities for childhood vaccination in office practices and the effect on vaccination status. *Pediatrics* **91**.

Recommended Adult Immunization Schedule—United States - 2014

Note: These recommendations must be read with the footnotes that follow containing number of doses, intervals between doses, and other important information.

Figure 1. Recommended adult immunization schedule, by vaccine and age group¹

VACCINE 🔻 AGE GROUP 🕨	19-21 years	22-26 years	27-49 years	50-59 years	60-64 years	≥ 65 years		
Influenza ^{2,*}			1 dose a	annually				
Tetanus, diphtheria, pertussis (Td/Tdap) 3,*		Substitute 1-tim	e dose of Tdap for Td b	ooster; then boost wit	h Td every 10 yrs			
Varicella ^{4,*}			2 de	oses				
Human papillomavirus (HPV) Female ^{s,*}	3 d	oses						
Human papillomavirus (HPV) Male ^{s,*}	3 d	oses						
Zoster ⁶		1						
Measles, mumps, rubella (MMR) ^{z,*}		1 or 2 dose	s					
Pneumococcal 13-valent conjugate (PCV13) 8,*			1 d	ose				
Pneumococcal polysaccharide (PPSV23) 9,10			1 or 2 doses			1 dose		
Meningococcal 11,*			1 or mo	re doses				
Hepatitis A 12,*			2 de	oses				
Hepatitis B ^{13,*}			3 da	oses				
Haemophilus influenzae type b (Hib) ^{14,*}			1 or 3	doses				

For all persons in this category who meet the age requirements and who lack documentation or vaccination or have no evidence of previous infection; zoster vaccine recommended regardless of prior episode of zoster



Recommended if some other risk factor is present (e.g., on the basis of medical, occupational, lifestyle, or other indication) http://www.cdc.gov/vaccines/schedules/downloads/adult/adult-combined-schedule.pdf

Figure 2. Vaccines that might be indicated for adults based on medical and other indications¹

VACCINE - INDICATION -	Pregnancy	Immuno- compromising conditions (excluding human immunodeficiency virus [HIV])4.6.7,8,15	HIV in CD4+ T ly count < 200 cells/µL	fection mphocyte 4,6,7,8,15 ≥ 200 cells/µL	Men who have sex with men (MSM)	Kidney failure, end-stage renal disease, receipt of hemodialysis	Heart disease, chronic lung disease, chronic alcoholism	Asplenia (including elective splenectomy and persistent complement component deficiencies) ^{8,14}	Chronic liver disease	Diabetes	Healthcare personnel
Influenza ^{2,*}		1 dose IIV anr	ually		1 dose IIV or LAIV annually		1 dos	e IIV annually			1 dose IIV or LAIV annually
Tetanus, diphtheria, pertussis (Td/Tdap) ^{3,*}	1 dose Tdap each prognancy	Si	ubstitut	e 1-time	e dose of	Tdap for Td b	ooster; the	n boost with Td e	every 1	0 yrs	
Varicella ^{4,*}	C	ontraindicated					2 d	oses			
Human papillomavirus (HPV) Female ^{5,*}		3 doses throu	igh age	26 yrs			3 dos	es through age 2	26 yrs		
Human papillomavirus (HPV) Male ^{5,*}		3 doses t	hrough	age 26	yrs		3 dos	es through age 2	21 yrs		
Zoster ⁶	C	ontraindicated						1 dose			
Measles, mumps, rubella (MMR) ^{7,*}	U	ontraindicated					1 or 2	doses			
Pneumococcal 13-valent conjugate (PCV13) ^{8,*}						1 d	ose				
Pneumococcal polysaccharide (PPSV23) 9,10						1 or 2 dos	es				
Meningococcal ^{11,*}				•		1 or more do	oses				
Hepatitis A ^{12,*}				•		2 doses					
Hepatitis B ^{13,*}				:		3 doses					
Haemophilus influenzae type b (Hib) 14,*		post-HSCT recipients only				1 or 3 dos	es				
*Covered by the Vaccine Injury Compensation Program For all pulack doc zoster va	ersons in this umentation o accine recom	category who meet t f vaccination or have mended regardless o	he age req no evidenc f prior epis	uirements a >e of previo ode of zost	and who us infection; er	Recor is pre- occup	nmended if som sent (e.g., on the ational, lifestyle,	e other risk factor basis of medical, or other indications)		No recor	nmendation

Statistics reported following the 2007 NIS of Adults ⁷:

- Only 57.2% of persons ages 18-64 and 44.1% of persons ages 65+ had received the tetanus, diphtheria vaccine (Td) recently enough to be considered still valid.
- Only 65.6% of persons 65+ had ever received the pneumococcal vaccine (a vaccine recommended for all persons in that age group)
- Only 1.9% of persons 60+ received the zoster vaccine (recommended for all persons in that age group)

⁷ CDC. 2010. *The National Immunization* Survey. Department of Health and Human Services, National Center for Health Statistics, United States. URL: www.cdc.gov/nis.

Aim

Provide freely available and easy to use automated tools for constructing catch-up schedules aimed at individuals, providers, and caretakers

Immediate benefits:

- Eliminate human error.
- Speedup the process.
- Improve public access to vital information.

Long-term benefits:

- Improve timely vaccination rates.
- Alleviate missed opportunities.
- Improve awareness participation.

Given past vaccination history, each remaining dose that can be feasibly administered and not contraindicated must be scheduled.

Feasibility requirements:

- minimum and maximum age requirement for each dose of each vaccine.
- Gap between (not necessarily successive) doses of the same vaccine must not violate the minimum allowed. This gap may vary by vaccine, dose, current age and/or age at which pervious dose is administered.
- "Live-virus" vaccines may be administered during the same visit or at least 28 days apart.

Given past vaccination history, each remaining dose that can be feasibly administered and not contraindicated must be scheduled.

Possible contraindications:

- The previous dose is administered at an age that no longer warrants further vaccination.
- The current age no longer warrants further vaccination.

Example (Contraindicating *PCV*)

The second dose of *PCV* is deemed final if the first dose is administered after age 12 months or the current age is 24-59 months. In either case, the third and fourth doses are unnecessary.

Given past vaccination history, each remaining dose that can be feasibly administered and not contraindicated must be scheduled.

Discretionary measures:

• The aggressiveness of catch-up regime, i.e.

Administer when recommended

VS

Administer as soon as feasibly possible

- The maximum number of simultaneous administrations.
- The number of doctor's visits.

The Catch-up Scheduling Problem & Machine Scheduling

Machine scheduling	Catch-up Scheduling					
Simila	arities					
Jobs	Vaccine doses					
Release and due dates	Window for each dose					
Number of processors	Number of simultaneous administrations					
Separation time between jobs	Spacing between doses					
(Chain) Precedence	Doses must be given in sequence					
Dissim	ilarities					
Processing time	Doses can be administered instantly					
Typically single objective (i.e. makespan, tardiness etc.)	 Multilevel objective: 1. Maximize completable vaccination series. 2. Maximize number of administered doses. 3. Minimize total delay in administering doses. 					
Typically constant separation times or setup time depends only on previous job	Spacing may vary by age and age any previous dose is given					

Complexity

- The catch-up scheduling problem remains NP-hard:
- 1. without minimum gap between doses and live vaccines,
- 2. without any maximum age for a dose and without live vaccines, and
- 3. without a limit on the number of simultaneous administrations.





Child's	Name: John Smith		
Birthda	te: 01/24/2011		
Va <mark>ccine</mark>	Description	# Cose	es Approximate dosage dates
HepB	Hepatitis B	1/3	Dose 1: 01/27/2011
RV	Rotavirus	1/3	Dose 1: 03/31/2011 + Add RV Dose 2
DTaP	Diphtheria, Tetanus, Pertussi	1/5	Dose 1: 03/18/2011
Hib	Haemophilus influenzae type	<u>b</u> 0/4	+ Add Hib Dose 1
PCV	Pneumococcal	0/4	+ Add PCV Dose 1
IPV	Polio	0/5	+ Add IPV Dose 1
MMR	Measles, Mumps, Rubella	0/2	+ Add MMR Dose 1
Var	<u>Varicella (Chickenpox)</u>	1/2	Dose 1: 01/01/2012
HepA	Hapatitic A	0/2	+ Add HepA Dose 1

The Tool (User Input and Interface) – Adult Immunization Scheduler

Q Adult Immunization Scheduler		
Ad Based o	ult Immunization S	If unknown, select the check box.
Name:	Birth Date : June	▼ 4 ▼ 1975 ▼ Sex: Male ▼
Vaccine Doses Administered Dates Administered Id 2 Id Idap 0 Id VAR 0 Id VAR 0 Id ZOS 0 Id PPSV23 0 Id HepA 0 Id HepB 1 01/07/2007 Do you have any of the medical corr Do you fall under any Do you fall under any Do you fall under any Do you fall under any Do you fall under any	Iministered in Chropological Order (in MM Approximate Dates are Accept Iministered in Chropological Order (in MM Approximate Dates are Accept Iministered in Chropological Order (in MM Approximate Dates are Accept Iministered in Chropological Order (in MM Approximate Dates are Accept Iministered in Chropological Order (in MM Part of the categories for which vaccination against meningood reen the ages of 9 and 26 who would like to be v	ADD/YYYY format only: able Do you smoke? Yes No Have you had the chicken pox? Yes No Have you had herpes zoster (shingles)? Yes No Have you bad herpes zoster (shingles)? Yes No Have you bad herpes zoster (shingles)? Yes No Have you bad herpes zoster (shingles)? Yes No Were you born in the United States? Yes No aska Native or American Indian younger than 65? Yes No bat had a lab test confirming immunity to varicella? Yes No Do you work in health-care? Yes No Do you work in health-care? Yes No Have you had a lab test confirming immunity to Do you work in health-care? Yes No Have you had a lab test confirming immunity to Isles or had a physician's diagnosis for measles? Yes No HepA is recommende? Yes Yes No Pactual is recommende? Yes Yes No Cucus is recommende? Yes Yes Yes No Cucus is recommende? Yes Yes Yes Yes
	Are you a resident of a nu	ursing home or long-term care facility?
	Do you have an im	munocompromising condition or HIV? 🔲 Yes 🗹 No Do you work in health-care? 🔽 Yes 🕅 No

The Tool (Vaccine Modeling Language)

ID	Name	Live?	Num. Doses		ses	Num. Dose Constraints		
5	PCV	No		4			6	

Dose	Min Age	Max Age	Max Age Prev. Dose	Rec.	Age	Rec. Gap to Next Dose		
		-		Min	Max	Min	Max	
1	6w	5у	_	2m	2m	4w	4w	
2	10w	5y	2у	4m	4m	8w	8w	
3	14w	5y	2у	6m	6m	6m	6m	
4	12m	5у	2у	12m	15m	_	_	

New Dees		Curre	nt Age	Age of Pr	ev Dose	Min Gap	
Next Dose	Prev Dose	Min	Мах	Min	Max	Between Dose	Final Dose?
2	1	0	<24m	0	<12m	4w	No
2	1	0	_	12m	_	8w	Yes
2	1	24m	59m	0	_	8w	Yes
3	2	0	<12m	0	_	4w	No
3	2	12m	_	0	_	8w	Yes
4	3	0	_	0	_	8w	Yes













Scheduled dose



Schedule S_x dominates S_y if:

- 1. The number of doses administered in
 - S_x is no less than S_y for each vaccine,
- 2. The timing of each critical dose
 - administered in S_{y} is no earlier than in
 - S_x, and
- 3. The total delay in administering doses in

If S_x dominates S_y then any completion of S_y cannot be better than



Dominance criteria

Schedule S_X dominates S_Y if:

1. The number of doses administered in

 $\mathbf{S}_{\mathbf{X}}$ is no less than $\mathbf{S}_{\mathbf{Y}}$ for each vaccine,

- 2. The timing of each critical dose
 - administered in S_{γ} is no earlier than in

S_x, and

3. The total delay in administering doses in

common is less in **S_x**.

Proposition

If S_x dominates S_y then any completion of S_y cannot be better than the best completion of S_x and thus, S_y is unwarranted.



Dominance criteria

Schedule S_X dominates S_Y if:

1. The number of doses administered in

 S_{X} is no less than S_{Y} for each vaccine,

- The timing of each critical dose administered in S_Y is no earlier than in S_x, and
- The total delay in administering doses in common is less in S_x.

Proposition

If S_X dominates S_Y then any completion of S_Y cannot be better than the best completion of S_X and thus, S_Y is unwarranted.

Output Charts – Childhood Catch-up Immunization Scheduler

Scenario 1

A 4 month old child who has received 1 dose of *HepB* at birth and one each of *DTaP*, *Hib* and *PCV* at 2 months of age.

Schedule^{*} generated for: on Nov 05, 2010 (11/05/2010) Birth Date: Jul 04, 2010 (07/04/2010). Current Age: 0 year/s, 4 month/s and 0 week/s

<u>Timeline</u>	0-4 weeks	1-2 months	3- mon	5 ths	6-11 months	12-14 months	15-17 months	18-23 months		4-6 years		
** Rec. Date (mm/dd/yy)	07/04/10	09/02/10	Today 11/05/10	12/03/10	01/04/11	07/04/11	10/04/11	01/04/12	06/04/12	07/04/14	07/04/16	Tally
HepB ¹	AD		CD		OD							3/3
Rota ²												0/3
DTaP_		AD	OD		OD		OD			OD		5/5
Hib ⁴		AD	OD		OD	OD						4/4
PCV ⁵		AD	OD		OD	OD						4/4
IPV_			CD	CD	OD					OD		4/5
MMR ⁷						OD				OD		2/2
<u>Var</u> ⁸						OD				OD		2/2
HepA ⁹						OD		OD				2/2
AD - Admini	stered D	ose C	D - Cat	ch-up Do	<u>se</u> <mark>Ol</mark>	<mark>D</mark> - <u>On-tir</u>	me Dose	PD	- Preemp	tive Dos	e	

Scenario 1... cont.

A 4 month old child who has received 1 dose of *HepB* at birth and one each of *DTaP*, *Hib* and *PCV* at 2 months of age.

Schedule^{*} generated for: on Nov 05, 2010 (11/05/2010) Birth Date: Jul 04, 2010 (07/04/2010). Current Age: 0 year/s, 4 month/s and 0 week/s

<u>Timeline</u>	0-4 weeks	1-2 months	r	3-5 nonths		12- mon	14 ths	15-17 months	18-2 mon	23 ths	4-6 yea	6 rs	
** Rec. Date (mm/dd/yy)	07/04/10	09/02/10	Today 11/05/10	12/03/10	12/31/10	07/04/11	08/05/11	10/04/11	01/04/12	06/04/12	07/04/14	07/04/16	Tally
HepB ¹	AD		CD		OD								3/3
Rota ²													0/3
DTaP		AD	OD	PD		PD					OD		5/5
Hib ⁴		AD	OD	PD		OD							4/4
PCV ⁵		AD	OD	PD		OD							4/4
IPV_			CD	CD	OD						OD		4/5
MMR ⁷						OD	PD						2/2
<u>Var</u> ⁸						OD		PD					2/2
HepA ⁹						OD			OD				2/2
AD - Admini	stered D	ose C	D - Cate	ch-up Do	<u>se</u> <mark>Ol</mark>	<mark>D</mark> - <u>On-ti</u>	me Dose	PD	- Preemp	tive Dos	e		

The Tool in Practice (Output Charts) – Canadian Immunization Scheduler

Scenario 1b

A 3-year-old child who is up-to-date on the recommended immunizations in Alberta, Canada

Schedule^{*} generated for: for Alberta on 25 Oct, 2010 (25/10/2010) Birth Date: 25 Jun, 2007 (25/06/2007). Current Age: 3 year/s, 4 month/s and 0 week/s

Timeline	2	3	6	12	18	3	4		7		10		12	14	15		16		
THICHIC	months	months	months	months	months	years	years		years		years		years	years	years		years		
** <u>Rec. Date</u> (dd/mm/yy)	25/08/07	23/10/07	30/12/07	30/06/08	30/12/08	Today 25/10/10	25/06/11	25/05/12	25/06/14	25/06/17	25/08/17	25/12/17	25/06/19	25/06/21	25/09/22	25/06/23	25/07/23	25/05/24	Tally
DTaP-IPV-Hib	AD	AD	AD		AD														4/4
DTaP-IPV							OD												1/1
Tdap														OD					1/1
<u>HB</u>										OD		OD							2/2
MMR_				AD			OD												2/2
<u>Var</u>				AD															1/1
Men-C	AD	AD		AD															3/3
MCV-4																			0/0
Pneu-C-7	AD	AD	AD		AD														4/4
<u>Inf</u> ¹⁰						One Dose R	Recommend	ed Annually											1/1
HPV ¹¹										OD	OD	OD							3/3
AD - Adminis	tered Do	<u>se</u> Cl) - <u>Catch</u>	n-up Dos	<u>e</u> OD	- <u>On-time Dose</u>	PD - Preem	ptive Dose											

Scenario 1b... cont.

A 3-year-old child who is up-to-date on the recommended immunizations in Alberta, Canada ... moves to British Columbia

Schedule^{*} generated for: for British Columbia on 25 Oct, 2010 (25/10/2010) Birth Date: 25 Jun, 2007 (25/06/2007). Current Age: 3 year/s, 4 month/s and 0 week/s

Timeline	2	3	6	12	18		3		4	7		11		13	14	16	i	17	
	months	months	months	months	months		years		years	years		years		years	years	yea	rs	years	
** <u>Rec. Date</u> (dd/mm/yy)	25/08/07	23/10/07	30/12/07	30/06/08	30/12/08	Today 25/10/10	20/12/10	25/02/11	25/06/11	25/06/14	25/06/18	25/08/18	25/12/18	25/06/20	25/06/21	25/06/23	25/10/23	25/06/25	<u>Tally</u>
DTaP-IPV-Hib	AD	AD	AD		AD														4/4
DTaP-IPV									OD										1/1
Tdap															OD				1/1
<u>HB</u>						CD	CD	CD											3/3
MMR				AD		CD													2/2
<u>Var</u>				AD															1/1
Men-C	AD	AD		AD															3/2
MCV-4																			0/0
Pneu-C-7	AD	AD	AD		AD														4/3
<u>Inf</u> ¹⁰																			0/1
HPV ¹¹											OD	OD	OD						3/3
AD - <u>Adminis</u>	tered Do	se Cl	D - <u>Catcl</u>	n-up Dos	<u>e</u> OD	- <u>On-tin</u>	ne Dose	PD-	Preempt	ive Dose									

Output Charts – Adult Immunization Scheduler

Scenario 2

A 35-year-old female who has received 1 dose of MMR, 3 doses of Td, and remembers the date of her last dose of Td.

Schedule^{*} generated for: on Oct 25, 2010 (10/25/2010) Birth Date: Apr 16, 1975 (04/16/1975). Current Age: 35 year/s, 6 month/s and 1 week/s



Scenario 2... cont.

A 35-year-old female who has received 1 dose of MMR, 3 doses of Td, does not remember her last dose of Td, and works in healthcare.

Schedule^{*} generated for: on Oct 25, 2010 (10/25/2010) Birth Date: Apr 16, 1975 (04/16/1975). Current Age: 35 year/s, 6 month/s and 1 week/s



 The Desktop Childhood Immunization Scheduler was available at: <u>http://www.cdc.gov/vaccines/recs/Scheduler/catchup.htm</u>

107,500+ downloads between June 2008 and March 2012

- Adult Immunization Scheduler: <u>http://www.cdc.gov/vaccines/schedules/easy-to-read/adult.html</u> 58,000+ downloads between January 2010 – September 2014
- Adolescent Immunization Scheduler: <u>http://www.cdc.gov/vaccines/schedules/easy-to-read/preteen-teen.html</u> 40,600+ downloads between March 2011 - September2014
- Online Childhood Scheduler
 400,000+ visits since January 2012, <u>https://www.vacscheduler.org/</u>
 <u>http://www.cdc.gov/vaccines/schedules/easy-to-read/child.html</u>





A New Tool to Manage Your Child's Vaccine Schedule



Online scheduler keeps track of missed immunizations

Entrepreneur[.]

Catch-up immunization software.



Tool Creates Personalized Catch-up Immunization Schedules For Missed Childhood Vaccinations

Universal Tool for Vaccine Scheduling

Thank You!

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- Children's Healthcare of Atlanta & Georgia Tech seed grant (administered by IPAT)

- Automated tools quickly solve catch-up scheduling problem faced on a daily basis by health-care professionals
 - User-friendly
 - Easily modified
 - Fast
 - Schedules meet guidelines and optimize coverage
- Optimization technology is easily adapted to various groups and countries

Future/Ongoing Work

- Use on mobile phones and other hand-held devices
- Online adolescent scheduler
- Develop a of a web-service to enable electronic health record systems (EHRs), personal health record systems (PHRs) and national immunization stakeholders such as state immunization information systems (IIS) to integrate with the tool
- Schedules for immunosupressed children (e.g., with diabetes, HIV, undergoing therapy, etc.)

- The "universal" catch-up scheduling problem
 - Problem description
 - Current paradigm
 - The need for an automated tool
- A dynamic programming (DP) algorithm
- The tool in practice
- Usage and dissemination



Recommended Immunization Schedule for Persons Aged 0 Through 6 Years—United States • 2010

Range of
DTaP ages for all
children except certain high-ris
PPSV
IPV
nza (Yearly) Range of recommended
see footnote ⁸ MMR ages for certain high-risk group
see footnote ⁹ Varicella
oses) HepA Series
MCV

For those who fall behind or start late, see the catch-up schedule

Approved by the Advisory Committee on Immunization Practices (http://www.cdc.gov/vaccines/recs/acip), the American Academy of Pediatrics (http://www.aap.org), and the American Academy of Family Physicians (http://www.aafp.org).

http://www.cdc.gov/vaccines/recs/schedules/downloads/child/2010/10_0-6yrs-schedule-pr.pdf

Problem Description: The Recommended Schedule

Recommended Immunization Schedule for Persons Aged 0 Through 6 Years—United States • 2009 For those who fall behind or start late, see the catch-up schedule

Vaccine▼ Age►	Birth	1 month	2 months	4 months	6 months	12 months	15 months	18 months	19–23 months	2–3 years	4–6 years	
Hepatitis B ¹	НерВ	He	рВ	see footnote 1		He	рB	á	5 5 5 6 6 8 8 8	त प + + - - - - - - - - - - - - - - - - -		
Rotavirus ²			RV	RV	RV ²	0 0 0 0 0 0 0 0 0	4 6 6 6 6 6 7 7 7			4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4		Range of recommended
Diphtheria, Tetanus, Pertussis ³			DTaP	DTaP	DTaP	see footnote3	D	<mark>laP</mark>	84 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	80 - a a a a a a a a a a a a a a a a a a	DTaP	ages
Haemophilus influenzae type b ⁴			Hib	Hib	Hib ^⁴	H	ib			9 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4		
Pneumococcal ⁵			PCV	PCV	PCV	P	<mark>CV</mark>			PF	sv	Certain
Inactivated Poliovirus			IPV	IPV		IF	V	•		80000000000000000000000000000000000000	IPV	groups
Influenza ⁶	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	P & +	7 4 4 4 4 4 4 4 4 4 4 4 4 4 4	* * * * * *		•	Influ	enza (Ye	arly)	4	*	
Measles, Mumps, Rubella ⁷				••••••••••••••••••••••••••••••••••••••		MI	MR	\$	ee footnote	7	MMR	
Varicella ⁸		90404000000000000000000000000000000000		**************************************		Vari	cella	s	ee footnote	8	Varicella	
Hepatitis A ⁹	# >4 +4 +4 +4 +# +7 +7 +4 +4 4 4 4 4 4 4 4 4 4 4 4 4 4 4						HepA (2 doses) ,	НерА	Series	
Meningococcal ¹⁰	=	14+4+14+4+4+4+4+4+4+4 5 5 6 6 5 5 5 5 5 5 5 5 5 5 5 5 5		**************************************	105564646464646 P 7 6 6 6 6 6 6 6 6 6 6 6 6 6	**************************************	n a ha ha ba ba da U dh bh bh bh P P ¢ ¢ ¢ b b	= bd Pd + d + d + b + b + b + b d 4 4 4 4 4 4 4 4 4 4 4 4 4	12 - 2 - 2 - 2 - 2 - 2 - 2 - 2 - 2 - 2 -	M	CV	

This schedule indicates the recommended ages for routine administration of currently licensed vaccines, as of December 1, 2008, for children aged 0 through 6 years. Any dose not administered at the recommended age should be administered at a subsequent visit, when indicated and feasible. Licensed combination vaccines may be used whenever any component of the combination is indicated and other components are not contraindicated and if approved by the Food and Drug Administration for that dose of the series. Providers should consult the relevant Advisory Committee on Immunization Practices statement for detailed recommendations, including high-risk conditions: http://www.cdc.gov/vaccines/pubs/acip-list.htm. Clinically significant adverse events that follow immunization should be reported to the Vaccine Adverse Event Reporting System (VAERS). Guidance about how to obtain and complete a VAERS form is available at http://www.vaers.hhs.gov or by telephone, 800-822-7967.

Problem Description: The Recommended Adult Schedule

Recommended Adult Immunization Schedule UNITED STATES - 2010 Note: These recommendations must be read with the footnotes that follow

containing number of doses, intervals between doses, and other important information.

Figure 1. Recommended adult immunization schedule, by vaccine and age group AGE GROUP► 19-26 years 27-49 years 50-59 years 60-64 years >65 years VACCINE -Tetanus, diphtheria, pertussis Td booster Substitute 1-time dose of Tdap for Td booster; then boost with Td every 10 yrs every 10 yrs (Td/Tdap)1,* Human papillomavirus (HPV)2,* 3 doses (females) Varicella^{3,*} 2 doses Zoster⁴ 1 dose Measles, mumps, rubella (MMR)5. 1 or 2 doses 1 dose Influenza^{6,*} dose annuall 1 or 2 doses Pneumococcal (polysaccharide)^{7,8} 1 dose Hepatitis A9,* 2 doses Hepatitis B10,* 3 doses Meningococcal^{11,*} 1 or more doses "Covered by the Vaccine Injury Compensation Program. Recommended If some other risk factor is present (e.g., on the basis of medical, occupational, lifestyle, or other indications) For all persons in this category who meet the age requirements and who lack evidence of immunity No recommendation (e.g., lack documentation of vaccination or have no evidence of prior infection) Report all clinically significant postvaccination reactions to the Vaccine Adverse Event Reporting System (VAERS). Reporting forms and instructions on filing a VAERS report are available at www.waers.hhs.gov or by telephone, 800-822-7967.

Information on how to file a Vaccine Injury Compensation Program claim is available at www.hrsa.gov/vaccinecompensation or by telephone, 800-338-2382. To file a claim for vaccine injury, contact the U.S. Court of Federal Claims, 717 Madison Place, N.W., Washington, D.C. 20005; telephone, 202-357-6400.

Additional information about the vaccines in this schedule, extent of available data, and contraindications for vaccination is also available at www.odc.gov/vaccines or from the CDC-INFO Contact Center at 800-CDC-INFO (800-232-4636) in English and Spanish, 24 hours a day, 7 days a week.

Use of trade names and commercial sources is for identification only and does not imply endorsement by the U.S. Department of Health and Human Services.

	doğumda	2.ayın sonunda	3.ayın sonunda	4.ayın sonunda	9.ayın sonunda	12.ayın sonunda	16-24.ay	İÖ 1.sınıfta	İÖ 8.sınıfta
BCG		I						R	
DBT		I	П	Ш			R		
Td								*	*
Hib		I	Ш	Ш			R		
OPV		I	Ш	Ш			R	R	
KKK (kızamık)						I		R	
Hepatit B	I	Ш			Ш				1-11-111

Recommended Immunization Schedule for Persons Aged 7 Through 18 Years—United States • 2010 For those who fall behind or start late, see the schedule below and the catch-up schedule

Vaccine ▼ Age ►	7–10 years	11–12 years	13–18 years	
Tetanus, Diphtheria, Pertussis ¹		Tdap	Tdap	Danas af
Human Papillomavirus ²	see footnote 2	HPV (3 doses)	HPV series	recommended ages for all
Meningococcal ³	MCV	MCV	MCV	children except certain high-risk
Influenza ⁴		Influenza (Yearly)		groups
Pneumococcal ⁵		PPSV		Bange of
Hepatitis A ⁶		HepA Series		recommended ages for
Hepatitis B ⁷		Hep B Series		catch-up immunization
Inactivated Poliovirus ⁸		IPV Series		
Measles, Mumps, Rubella ⁹		MMR Series		Range of recommended
Varicella ¹⁰		Varicella Series		ages for certain high-risk groups

Approved by the Advisory Committee on Immunization Practices (http://www.cdc.gov/vaccines/recs/acip), the American Academy of Pediatrics (http://www.aap.org), and the American Academy of Family Physicians (http://www.aafp.org).

http://www.cdc.gov/vaccines/recs/schedules/downloads/child/2010/10_7-18yrs-schedule-pr.pdf

Publicly funded Immunization Programs in Canada - Routine Schedule for Infants and Children (including special programs and catch-up programs)

Province/ Territory	DTaP- IPV-Hib	DTaP- IPV	Td, Tdap or Td-IPV	НВ	MMR	Var	Men-C	Menactra- (Groups A, C, Y, W-135 conjugate)	Pneu-C- 7	Inf	HPV
NACI recom- mendation	2,4,6,18 mths	4-6 yrs	14-16 yrs	Infancy (3 doses) OR Pre- teen/teen	12 mths, 18m/4-6 yrs	Children between 12 & 18 mths	2, 4, 6 mths OR 12 mths, if not yet given OR 14-16 yrs, if not yet given	High risk individuals 2-55 yrs of age ²	2, 4, 6, 12/15 mths	6-23 mths (1-2 doses)	Females 9- 26 yrs (3 doses at 0, 2 and 6 months) ¹
BC	2,4,6,18 mths	4-6 yrs	dTap, Gr 9	2,4,6 mths Gr 6 Catch- up (2 doses)	12, 18 mths	12 mths, 4-6 yr olds, and Grade 6	2,12 mths Gr 6 catch-up		Healthy children: 2,4,12 mths High risk children: 2,4,6,12 mths	6-23 mths	Starting in Sept 2008: Females in Gr 6 and Gr.9 (3 doses given @ 0, 2, 6 mos)
АВ	2,4,6,18 mths	4-6 yrs	dTap, Gr 9	Gr. 5	12 mths, 4-6 yrs	12 mths	2, 4 and 12 months		2,4,6,18 mths	6-59 mths	Starting in Sept 2008: Females in Gr 5. Gr 9 girls from 2009 to 2012

Catch-up Immunization Schedule for Persons Aged 4 Months Through 18 Years Who Start Late or Who Are More Than 1 Month Behind—United States • 2010

The table below provides catch-up schedules and minimum intervals between doses for children whose vaccinations have been delayed. A vaccine series does not need to be restarted, regardless of the time that has elapsed between doses. Use the section appropriate for the child's age.

		PERSONS AGED 4 MONT	THS THROUGH 6 YEARS		
Vacaina	Minimum Age		Minimum Interval Between Doses		
vaccine	for Dose 1	Dose 1 to Dose 2	Dose 2 to Dose 3	Dose 3 to Dose 4	Dose 4 to Dose 5
Hepatitis B1	Birth	4 weeks	8 weeks (and at least 16 weeks after first dose)		
Rotavirus ²	6 wks	4 weeks	4 weeks ²		
Diphtheria, Tetanus, Pertussis ³	6 wks	4 weeks	4 weeks	6 months	6 months ³
Haemophilus influenzae type b4	6 wks	4 weeks if first dose administered at younger than age 12 months 8 weeks (as final dose) if first dose administered at age 12–14 months No further doses needed if first dose administered at age 15 months or older	4 weeks ⁴ if current age is younger than 12 months 8 weeks (as final dose) ⁴ if current age is 12 months or older and first dose administered at younger than age 12 months and second dose administered at younger than 15 months No further doses needed	8 weeks (as final dose) This dose only necessary for children aged 12 months through 59 months who received 3 doses before age 12 months	
Pneumococcal ⁶	6 wks	4 weeks if first dose administered at younger than age 12 months 8 weeks (as final dose for healthy children) if first dose administered at age 12 months or older or current age 24 through 59 months No further doses needed for healthy children if first dose administered at age 24 months or older	It previous dose administered at age 15 months or older 4 weeks if current age is younger than 12 months 8 weeks (as final dose for healthy children) if current age is 12 months or older No further doses needed for healthy children if previous dose administered at age 24 months or older	8 weeks (as final dose) This dose only necessary for children aged 12 months through 59 months who received 3 doses before age 12 months or for high- risk children who received 3 doses at any age	
nactivated Poliovirus ⁶	6 wks	4 weeks	4 weeks	6 months	
leasles,Mumps, Rubella ⁷	12 mos	4 weeks			
/aricella ⁸	12 mos	3 months			
lepatitis A ⁹	12 mos	6 months			
-		PERSONS AGED 7 T	HROUGH 18 YEARS		
Tetanus, Diphtheria/ Tetanus, Diphtheria, Pertussis ¹⁰	7 yrs ¹⁰	4 weeks	4 weeks if first dose administered at younger than age 12 months 6 months if first dose administered at 12 months or older	6 months if first dose administered at younger than age 12 months	
Human Papillomavirus ¹¹	9 yrs	R	outine dosing intervals are recommended ¹¹		RED
Hepatitis A ⁹	12 mos	6 months			I L L
lepatitis B ¹	Birth	4 weeks	8 weeks (and at least 16 weeks after first dose)		
nactivated Poliovirus ⁶	6 wks	4 weeks	4 weeks	6 months	Supplementation of
Measles,Mumps, Rubella ⁷	12 mos	4 weeks			
Varicella ⁸	12 mos	3 months if person is younger than age 13 years 4 weeks if person is aged 13 years or older			American

Catch-up Immunization Schedule for Persons Aged 4 Months Through 18 Years Who Start Late or Who Are More Than 1 Month Behind—United States • 2009

The table below provides catch-up schedules and minimum intervals between doses for children whose vaccinations have been delayed. A vaccine series does not need to be restarted, regardless of the time that has elapsed between doses. Use the section appropriate for the child's age.

	CA	TCH-UP SCHEDULE FOR PERSONS	S AGED 4 MONTHS THROUGH 6 Y	EARS	
Vaccine	Minimum Age		Minimum Interval Between Do	oses	
Vaccille	for Dose 1	Dose 1 to Dose 2	Dose 2 to Dose 3	Dose 3 to Dose 4	Dose 4 to Dose 5
Hepatitis B ¹	Birth	4 weeks	8 weeks (and at least 16 weeks after first dose)		
Rotavirus ²	6 wks	4 weeks	4 weeks ²		
Diphtheria, Tetanus, Pertussis ³	6 wks	4 weeks	4 weeks	6 months	6 months ³
Haemophilus influenzae type b ⁴	6 wks	4 weeks if first dose administered at younger than age 12 months 8 weeks (as final dose) if first dose administered at age 12-14 months No further doses needed if first dose administered at age 15 months or older	4 weeks ⁴ if current age is younger than 12 months 8 weeks (as final dose) ⁴ if current age is 12 months or older and second dose administered at younger than age 15 months No further doses needed if previous dose administered at age 15 months or older	8 weeks (as final dose) This dose only necessary for children aged 12 months through 59 months who received 3 doses before age 12 months	
Pneumococcal ⁵	6 wks	4 weeks if first dose administered at younger than age 12 months 8 weeks (as final dose for healthy children) if first dose administered at age 12 months or older or current age 24 through 59 months No further doses needed for healthy children if first dose administered at age 24 months or older	4 weeks if current age is younger than 12 months 8 weeks (as final dose for healthy children) if current age is 12 months or older No further doses needed for healthy children if previous dose administered at age 24 months or older	8 weeks (as final dose) This dose only necessary for children aged 12 months through 59 months who received 3 doses before age 12 months or for high-risk children who re 3 doses at any ag	BOOK*
Inactivated Poliovirus ⁶	6 wks	4 weeks	4 weeks	4 weeks ⁶	BOOK
Measles, Mumps, Rubella ⁷	12 mos	4 weeks		Margert 10 Margert 10 Margert 10 Margert 10 Margert 10	and all and
Varicella ⁸	12 mos	3 months			
Hepatitis A ⁹	12 mos	6 months		Anarte	an Arabam of Padawish

Problem Description: The Recommended Adult Schedule

Recommended Adult Immunization Schedule

UNITED STATES • 2010 Note: These recommendations must be read with the footnotes that follow

containing number of doses, intervals between doses, and other important information.

Figure 1. Recommended adult immunization schedule, by vaccine and age group

VACCINE	19–26 years	27–49 years	50–59 years	60–64 years	<u>≥</u> 65 years
Tetanus, diphtheria, pertussis (Td/Tdap) ^{1,:}	Substitute 1-time d	lose of Tdap for Td b	ooster; then boost w	vith Td every 10 yrs	Td booster every 10 yrs
Human papillomavirus (HPV) ^{2,*}	3 doses (females)				
Varicella ^{2,*}			2 doses		
Zoster				1 d	ose
Measles, mumps, rubella (MMR) ^{s,*}	1 or 2	doses		1 dose	
Influenza ^{s,•}		1	dose annuall	у	
Pneumococcal (polysaccharide) ^{7,3}		1 or 2	doses		1 dose
Hepatitis Aª.'			2 doses		
Hepatitis B ^{10,*}			3 doses		
Meningococcal ^{11.*}			1 or more doses		
*Covered by the Vaccine Injury Compensation Program.	For all persons in th requirements and w (e.g., lack documen no evidence of prior	l is category who meet the age ho lack evidence of immunity tation of vaccination or have infection)	Recommended If present (e.g., on occupational, life	some other risk factor is the basis of medical, style, or other indications)	No recommendation
Report all clinically significant postvaccination reac telephone, 800-822-7967. Information on how to file a Vaccine Injury Comper Federal Claims, 717 Madison Piace, N.W., Washing	tions to the Vaccine Adverse Event isation Program claim is available a ton, D.C. 20005; telephone, 202-35	Reporting System (VAERS). Report t www.hrsa.gov/vaccinecompensa 7-6400.	ting forms and instructions on filir tion or by telephone, 800-338-238	ng a VAERS report are available at v 2. To file a claim for vaccine injury,	www.vaers.hhs.gov or by contact the U.S. Court of

Additional information about the vaccines in this schedule, extent of available data, and contraindications for vaccination is also available at www.cdc.gov/vaccines or from the CDC-INFO Contact Center at 800-CDC-INFO (800-232-4636) in English and Spanish, 24 hours a day, 7 days a week.

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Problem Description: The Recommended Adult Schedule (Cont.)

Figure 2. Vaccines that might be indicated for adults based on medical and other indications

INDICATION >	Pregnancy	Immuno- compromising conditions (excluding human Immunodeficiency virus [HIV]) ^{2+,0}	HIV Infection=+d.12 CD4+ T lympho- cyte count <200 cells/µL cells/µL	Diabetes, heart disease, chronic lung disease, chronic alcoholism	Aspienia" (including elective spienectomy and persistent complement deficiencies)	Chronic liver disease	Kidney failure, end-stage renai disease, receipt of hemodialysis	Health-care personnel	
Tetanus, diphtheria, pertussis (Td/Tdap) ^{1.*}	Td	Substit	ute 1-time de	ose of Tdap fo	o <mark>r Td booste</mark> r	; then boost	with Td every	/ 10 yrs	
Human papillomavirus (HPV) ^{2,•}				3 doses for fe	emales throu	gh age 26 yrs	5		
Varicella ^{a,•}	Cont	raindicated			2	2 doses			
Zoster	Cont	raindicated			·	1 dose			
Measles, mumps, rubella (MMR) ^{s,·}	Cont	raindicated			1 o	r 2 doses			
Influenza ^{s,*}			1 d	ose TIV annu	ally			1 dose TIV or LAIV	
Pneumococcal (polysaccharide) ^{7,8}				1 or 2	doses			annually	
Henatitis A ^{s,}				2 da	ses				
Henstitie Bu:				2 da					
nepaulis D				3 00					
Meningococcal ^{11,*}				1 or mo	re doses				
For all persons in this category who meet the age requirements and who lack evidence of immunity (e.g., lack documentation of vaccination or have no evidence of prior infection)									
These schedules indicate the recommended age groups and medical indications for which administration of currently licensed vaccines is commonly indicated for adults ages 19 years and older, as of January 1, 2010. Licensed combination vaccines may be used whenever any components of the combination are indicated and when the vaccine's other components are not contraindicated. For detailed recommendations on all vaccines, including those used primarily for travelers or that are issued during the year, consult the manufacturers' package inserts and the complete statements from the Advisory Committee on Immunization Practices (www.cdc.gov/vaccines/pubs/acip-list.htm).									

The recommendations in this schedule were approved by the Centers for Disease Control and Prevention's (CDC) Advisory Committee on Immunization Practices (ACIP), the American Academy of Family Physicians (AAFP), the American College of Obstetricians and Gynecologists (ACOG), and the American College of Physicians (ACP).



Problem Description: The Recommended Adult Schedule (Cont.)

Figure 2. Vaccines that might be indicated for adults based on medical and other indications

INDICATION >	Pregnancy	lmmuno- compromising conditions (excluding human immunodeficiency virus (HIVI) ¹³	HIV Infection ^{3,12,13} CD4+ T lympho- cyte count		Diabetes, heart disease, chronic lung disease, chronic	Aspienia ¹² (including elective spienectomy and persistent complement	Chronic liver disease	Kidney failure, end-stage renal disease, receipt of	Health-care personnel
			<200 cells/µL	≥200 cells/µL	alcoholism	deficiencies)		nemodiarysis	
Tetanus, diphtheria, pertussis (Td/Tdap) ^{1,*}	Td	Substit	ute 1-t	ime do	se of Tdap f	or Td booster	; then boost	with Td every	10 yrs
Human papillomavirus (HPV) ^{2,*}		3 d		3 doses for f	doses for females through age 26 yrs				
Varicella ^{3,*}	Cont	raindicated				2	doses	1	
Zoster ⁴	Cont	raindicated					1 dose		
Measles, mumps, rubella (MMR) ^{5,*}	Cont	raindicated				10	r 2 doses		
Influenza ^{6,*}		1 dose TIV annually						1 dose TIV or LAIV	
Pneumococcal (polysaccharide) ^{7,8}					1 or 2	doses			annuall
Hepatitis A ^{9,*}				<u> </u>	2 de	oses			
Hepatitis B ^{10,*}				<u> </u>	3 d	oses			
Meningococcal ^{11,*}	1			+	1 or mo	re doses			
uned by the Unersky link of Componentian Deserve				Ľ.					
vereu by ne vacche niju y compensation Program.	For all require (e.g., no evic	persons in this categ ments and who lack lack documentation o lence of prior infectio	ery who m evidence o l'vaccinati n)	eet the age of Immunity on or have	;	Recommended If son present (e.g., on the occupational, lifestyl	ne other risk factor i: basis of medical, ie, or other indicatio	s Ins)	No recommenda

The recommendations in this schedule were approved by the Centers for Disease Control and Prevention's (CDC) Advisory Committee on Immunization Practices (ACIP), the American Academy of Family Physicians (AAFP), the American College of Obsteblicians and Gynecologists (ACOG), and the American College of Physicians (ACP).



Possible reasons for incorrect and untimely vaccination of adults ⁸:

- never vaccinated as children
- new vaccines which were unavailable during childhood
- fading immunity
- higher susceptibility to some diseases with age
- · changes in medical condition, work environment, and lifestyle

⁸ CDC. 2010. *Adult Immunization Schedule*. National Centers for Immunization and Respiratory Diseases. URL: http://www.cdc.gov/vaccines/recs/schedules/adult-schedule.htm.

Given past vaccination history, each remaining dose that can be feasibly administered and not contraindicated must be scheduled.

Feasibility requirements:

- Minimum and maximum age requirement for each dose of each vaccine.
- Gap between (not necessarily successive) doses of the same vaccine must not violate the minimum allowed. This gap may vary by vaccine, dose, current age and/or age at which pervious dose is administered.
- "Live-virus" vaccines may be administered during the same visit or at least 28 days apart.

Given past vaccination history, each remaining dose that can be feasibly administered and not contraindicated must be scheduled.

Possible contraindications:

- The previous dose is administered at an age that no longer warrants further vaccination.
- The current age no longer warrants further vaccination.

Example (Contraindicating *PCV*)

The second dose of *PCV* is deemed final if the first dose is administered after age 12 months or the current age is 24-59 months. In either case, the third and fourth doses are unnecessary.

Given past vaccination history, each remaining dose that can be feasibly administered and not contraindicated must be scheduled.

Discretionary measures:

• The aggressiveness of catch-up regime, i.e.

Administer when recommended

VS

Administer as soon as feasibly possible

- The maximum number of simultaneous administrations.
- The number of doctor's visits.

The Catch-up Scheduling Problem & Machine Scheduling

Machine scheduling	Catch-up Scheduling				
Similarities					
Jobs	Vaccine doses				
Release and due dates	Window for each dose				
Number of processors	Number of simultaneous administrations				
Separation time between jobs	Spacing between doses				
(Chain) Precedence	Doses must be given in sequence				
Dissimilarities					
Processing time	Doses can be administered instantly				
Typically single objective (i.e. makespan, tardiness etc.)	 Multilevel objective: 1. Maximize completable vaccination series. 2. Maximize number of administered doses. 3. Minimize total delay in administering doses. 				
Typically constant separation times or setup time depends only on previous job	Spacing may vary by age and age any previous dose is given				

Proposition

- The catch-up scheduling problem remains NP-hard:
- 1. without minimum gap between doses and live vaccines,
- 2. without any maximum age for a dose and without live vaccines, and
- 3. without a limit on the number of simultaneous administrations.

The Tool





Catch-up Scheduling for Childhood immunization

The Tool (Vaccine Library)

Example (Vaccine Library File for *PCV*)

ID	Name	Live?	Num. Doses		ses	Num. Dose Constraints		
5	PCV	No		4			6	

Dose	Min Age	Max Age	Max Age Rec Prev. Dose		Age	Rec. G Next	ap to Dose
				Min	Max	Min	Max
1	6w	5у	_	2m	2m	4w	4w
2	10w	5y	2у	4m	4m	8w	8w
3	14w	5y	2у	6m	6m	6m	6m
4	12m	5у	2у	12m	15m	_	_

		Current Age		Age of Prev Dose		Min Gap		
Next Dose	Prev Dose	Min	Мах	Min	Max	Between Dose	Final Dose?	
2	1	0	<24m	0	<12m	4w	No	
2	1	0	_	12m	_	8w	Yes	
2	1	24m	59m	0	_	8w	Yes	
3	2	0	<12m	0	_	4w	No	
3	2	12m	_	0	_	8w	Yes	
4	3	0		0		8w	Yes	













Dominance criteria

Schedule S_X dominates S_Y if:

1. The number of doses administered in

 $\mathbf{S}_{\mathbf{X}}$ is no less than $\mathbf{S}_{\mathbf{Y}}$ for each vaccine,

- The timing of each critical dose administered in S_Y is no earlier than in S_X, and
- The total delay in administering doses in common is less in S_x.

Proposition

If S_X dominates S_Y then any completion of S_Y cannot be better than the best completion of S_X and thus, S_Y is unwarranted.

User Input and Interface – Childhood Catch-Up Immunization Scheduler

Catchup Immunization Scheduler	
For children six years and younger	
Based on 2010 Childhood Immunization Schedule Birth Date: July 4 2010 Name Child's Name Child's Name Child's Name Accelerated Schedule Routine Schedule	
Vaccine Doses Administered Dates Administered (in MM/DD//// format only) HepB 1 7/4/2010 Rota 0 - DTaP 1 9/2/2010 Hib 1 9/2/2010 PCV 1 9/2/2010 IPV 0 - MMR 0 - HepA 0 -	
Get Schedule Reset Save Retrieve Doses	

The Tool (User Input and Interface) – Canadian Immunization Scheduler

Canadian Immunization Scheduler	dian atric ty Working for kids since 1922 United States of the Canadian Immunization Scheduler Based on the Canadian Nursing Coalition on Immunization, 2004		
Name: Mary Province/T Vaccine Doses Administered DTaP-IPV-Hib 3 Tdap 0 JB 1 Var 0 MMR 1 Var 0 Men-C 0 McV-4 0 Pneu-C-7 0 HPV 0 Calendar Help	Birth Date : 24 June erritory of Residence: Ontario Dates Administered in Chronological Order (in DD/MM/YYYY format only) (estimated dates are fine) 12/08/2004 21/10/2004 231/12/2004 23 Contemporation (Contemporation) Contemporation (Contemporation) Contemp	2004 Check below if dates unknown V V V O	Check below if dates unknown

Province/Territory of Residence:

Ontario

The Tool (Output Charts)

Scenario 2

A 1 year old child who is presumed not received any vaccination to date.



*Dose may be administered anytime during specified interval. However, gap to subsequent doses may not be valid when administered after first day in interval.

Catch-up Scheduling for Childhood immunization

The Tool (Output Charts)

Scenario 2... cont.

A 1 year old child who is presumed not received any vaccination to date.



*Dose may be administered anytime during specified interval. However, gap to subsequent doses may not be valid when administered after first day in interval.

Catch-up Scheduling for Childhood immunization

- 1. User-friendly for providers to use on a regular basis
- 2. Easily modified to accommodate changes to the recommended schedule
- 3. Return a user's recommended immunization schedule quickly
- 4. Return a recommended immunization schedule that meets all guidelines and optimizes an individual's coverage against vaccine-preventable diseases