

Supplementary information

Long-term immune responses to vaccination in HIV-infected patients: a systematic review and meta-analysis.

1. Search equation

(Vaccin* [Mesh]) AND (Antibodies, Bacterial[Mesh] OR Antibodies, Viral[Mesh]) AND (Follow-Up[All Fields] OR long-term[All Fields] OR persistence[All Fields] OR decline[All Fields] OR duration[All Fields] OR antibody kinetics[All Fields] OR antibody decay[All Fields]) AND English[lang] AND((HIV[All Fields] NOT AIDS Vaccines[Mesh]))

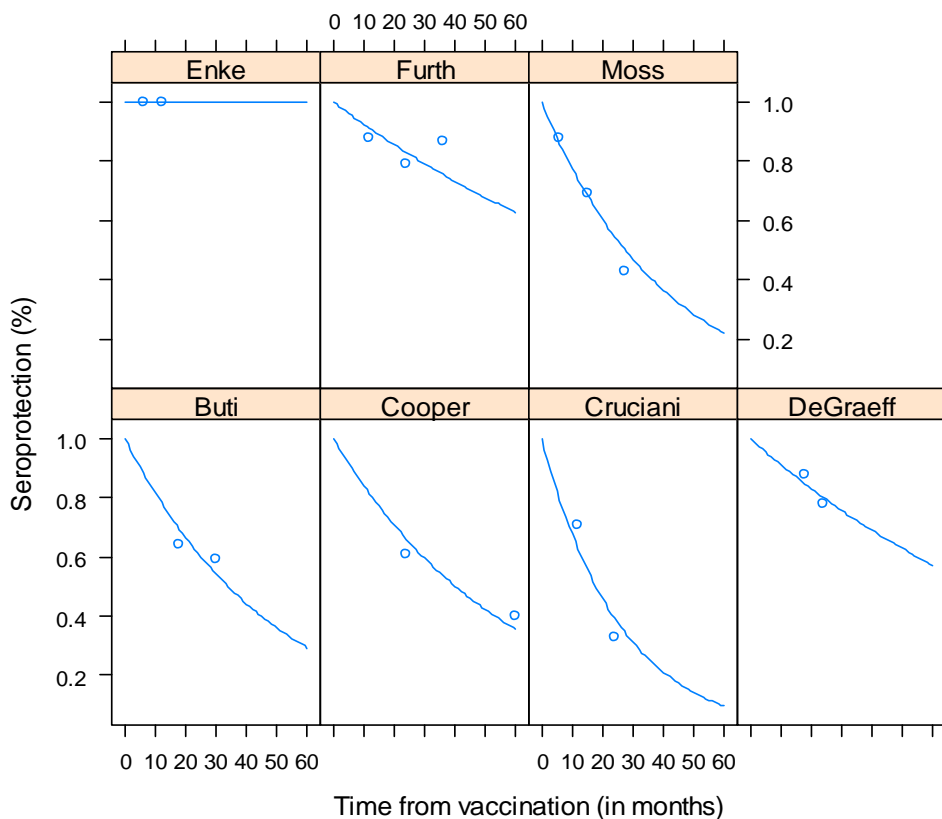
2. Model fit

We used an exponential decrease to model the change in percentage seroprotected with time, according to :

$$P_i(t) = \exp(-\beta_i t)$$

where $P_i(t)$ is the percentage seroprotected at time t in study i , and β_i is the exponential rate of decrease in study i to be estimated. Parameters were estimated at maximum likelihood using log-binomial generalized linear models.

Obviously, as the model uses one parameter, an exact fit is expected in studies where only one measurement was reported after the last vaccination. We therefore show below the fit of this model in studies where seroprotection was measured on several occasions over time, irrespective of the vaccine or population. Results are presented for studies conducted in different categories of immunocompromised patients: HIV-infected patients (Cooper, Cruciani and Moss), hemodialysis patients (Buti, De Graeff) and solid organ transplants (Enke, Furth).



While simple, the exponential decrease model for percentage seroprotected captures well the trend over time, in the three categories of patients. In the only study reporting data up to 5 years after vaccination, the fit was also satisfactory at both measurement times (24 and 60 months, Cooper, see above), suggesting that extrapolation at these two dates was reasonable.

3. Model extrapolation

In all studies, the seroprotection level was extrapolated at T=2 and T=5 years after vaccination using the model described above. At time T, in the i -th study, we computed:

$$\hat{P}_i(T) = \exp(-\hat{\beta}_i T)$$

The variance of the extrapolation was the conditional variance given the observed data:

$$\text{Var}(\hat{P}_i(T) | \{P_i(t_{ij})\}_j, N_i) = T^2 \hat{P}_i^2(T) \text{Var}(\hat{\beta}_i)$$

Where N_i was the number of persons in study i , $P_i(t_{ij})$ the observed percentages at time t_{ij} and $\text{Var}(\hat{\beta}_i)$ was estimated from the log-binomial model fit.

4. Proportion meta-analysis

We performed a meta-analysis of the extrapolated seroprotection levels at time 2 and 5 years. We used the Der Simonian-Laird random effects approach to summarize the data. Proportions were first transformed using the Freeman-Tukey arcsine square root transformation, and the meta-analysis result was back transformed to a proportion. When no loss of seroprotection was reported over time, we arbitrarily added one event to the calculations to conduct the meta-analysis.

5. Antibody decrease models and percentage seroprotected

In the meta-analysis, we modeled the percentage seroprotected over time, using a negative exponential function. This does not imply a particular choice for the actual intra-individual loss of immunity. We give here two examples to show that different antibody level decrease models can lead to the same percentage of seroprotected individuals over time.

The first model is an exponential decrease of antibody with time: $A_1(t) = A_0 \exp(-t/\alpha)$, and the second implies a power-law decrease over time: $A_2(t) = A_0 / (1+t)^{1/\alpha}$. In both models, we assume for simplicity that the baseline antibody measurement after vaccination A_0 is not patient dependent, and that α is a random parameter controlling the decrease of antibodies over time (obviously, its meaning, and value, is different in A_1 and A_2). For the first model, we further assume an exponential distribution for α with cumulative distribution function $F_1(\alpha) = 1 - \exp(-\beta \ln(A_0/L) \alpha)$, and in the second model, we assume an extreme value distribution with $F(\alpha) = 1 - \exp(-\beta (\exp(\ln(A_0/L) \alpha) - 1))$, where β is a constant.

In both cases, the percentage seroprotected at date T is computed according to: $P(T) = P(A(t) > L)$. This leads, in the first instance, to $F_1(T/\ln(A_0/L)) = \exp(-\beta T)$, and in the second instance to

$$F_2(\ln(1+T) / \ln(A_0/L)) = \exp(-\beta T).$$

Therefore, the above example shows that the form we assumed for the percentage seroprotected over time is compatible with various intra-individual models for antibody levels decrease. In each case, however, a specific combination of a model for decrease and the distribution of the individual parameters will be required.

6. Table 1: Data retrieved from studies included in the meta-analysis

Author, year	Vaccine	Vaccine scheme	Age class	Responders (N)	Assay used, protective titer	Time from last vaccine dose, percentage above protective titer among initial responders	Clinical and immuno-virological data
Hepatitis B							
Lao-araya, 2011	Recombinant HBV vaccine (Government Pharmaceutical Organization-Merieux Biological Product, Bangkok, Thailand)	3 doses 10 µg M0-M2-M6 (IM)	Children	66	AUSAB enzyme-linked immunoassay diagnostic kits (Abbott Laboratories, Abbott Park, IL, USA), ≥10 UI	36 months, 74%	At the time of immunization: mean age 12.9 years (±2.2).34 (49%) on CDC-stage C. Mean CD4 cell count: 731/µL (±264). Mean HIV RNA level 5.4 log copies/mL (±0.4), 63 (91%) with HIV RNA levels<1.7 log copies/mL. All children on HAART at the time of immunization.
Scolfaro, 1996	Engerix B® (Smith&Kline, Nanterre, France)	3 doses 10 µg M0-M1-M6 (IM) + 1 booster 20 µg in non-responders	Children	14	NA, ≥10 UI	16 months, 42%	At the time of immunization: Median age 38 months (range: 1-102). 3 (30%) on CDC-stage C. Median CD4 cell count 950/µL.
Manucci, 1989	Hevac B® (Pasteur Vaccines, Paris, France)	3 doses 5 µg M0-M1-M2 (SC) + 1 booster 5 µg at M14	Both	11	ELISA, ≥10 UI	34 months, 55%	Haemophiliac patients. Median age 11 years (range: 4 to54).
Kaech, 2012	Engerix B-20®	3 doses 20 µg M0-M1-M6 (IM)	Adults	23	ELISA, ≥10 UI	12 months, 65% 24 months, 52%	Population of patients with isolated anti-HBcIgG. At the time of immunization: median age 42 years (Interquartile range, IQR: 32-48). Median CD4 cell count 443/µL (IQR:352-579). 28 (76%) with undetectable HIV viral load. Plasma HIV RNA level 2.9 log copies/mL (IQR: 2.3-4.5) in non-suppressed patients. 33 (89%) on HAART at the time of immunization.
Rey, 2000	Genhevax B® (Pasteur vaccins, Lyon, France)	3 doses 20 µg M0-M1-M2 (IM) + 3 booster doses 20 µg M3-M4-M5 for non-responders (n= 9)	Adults	17	Enzyme immunoassay method (Abbott AXSYM), ≥10 UI	12 months, 59%	At the time of immunization: median age 30.5 years (range: 22-52). None on CDC-stage C. 17 (85%) on HAART at the time of immunization. Median CD4 cell count 470/µL (range: 224-1414). Median HIV RNA level 3.37 log copies/mL (range: <2.3-4.6), 2 (13%) with undetectable HIV RNA levels.
Cooper, 2008	Engerix B® (Glaxo-SmithKline)	3 doses 40 µg M0-M1-M2 (IM)	Adults	18 15	Abbott AUSAB EIA, ≥10 UI	24 months, 61% 60 months, 40%	At the time of immunization: mean age 42.9 years (±7.3). Median CD4 cell count 543/µL (±228). All on HAART with undetectable HIV viral load at the time of immunization.
Cruciani, 2009	HBVAXPRO® 40 µg/ml (Aventis Pasteur MSD Spa, Rome, Italy)	3 doses 40 µg M0-M1-M2 (IM) + 1 to 3 boosters 40µg M3-M4-M5	Adults	58	NA, ≥10 UI	12 months, 71% 24 months, 33%	At the time of immunization: mean age 41 years (±8). 4 on CDC-stage C. Median CD4 cell count 533/µL (range: 219 -1298). Mean HIV RNA level <100 copies/mL (<100-814560). 74 patients (80%) on HAART at the time of immunization.

Author, year	Vaccine	Vaccine scheme	Age class	Responders (N)	Assay used, protective titer	Time from last vaccine dose, percentage above protective titer among initial responders	Clinical and immuno-virological data at study entry
Hepatitis A							
Weinberg, 2006	HAVRIX® (Glaxo-SmithKline)	2 doses M0-M6 (IM)	Children	120	Quantitative ELISA, ≥20 UI	18 months, 92%	At the time of immunization: median age 9.1 years (2 to 21). Median CD4 cell count 856/μL. Median HIV RNA level 483 copies/mL (49% with undetectable HIV RNA levels).
Crum Cianflone, 2011	VAQTA® (Merck) or HAVRIX® (Glaxo-SmithKline)	2 doses M0-M6 (IM)	Adults	116	Quantitative HAVK Plus EI (MerckResearchLaboratories), ≥10 UI	36 months, 90%	At the time of immunization: median age 35 years (range: 30- 41).Median CD4 cell count 461/μL (IQR: 322-617). 63 (49%) with HIV RNA level <1000 copies/mL.. 81 (62%) on HAART at the time of immunization.
Kernéis, 2011	HAVRIX® 1440; GlaxoSmithKline, Marly le Roi, France)	3 doses M0-M1-M6(IM) or 2 doses M0-M6(IM)	Adults	26 26	Enzyme-linked immunosorbent assay method (ETI-ABHAVK PLUS; DiaSorin, Saluggia, Italy). , ≥20 UI	45 months, 85% 45 months, 85%	At the time of immunization: median age 39.5 years (IQR: 33.9 – 43.3), 14 (27%) on CDC-stage C, median CD4 cell count 362/μL (IQR: 295-405). 32 (62%) with HIV RNA level <50 copies/mL.
Launay, 2008	HAVRIX® 1440; GlaxoSmithKline, Marly le Roi, France).	3 doses M0-M1-M6 (IM) 2 doses M0-M6 (IM)	Adults	42 43	Enzyme-linked immunosorbent assay method (ETI-ABHAVK PLUS; DiaSorin, Saluggia, Italy). , ≥20 UI	11 months, 100% 11 months, 100%	At the time of immunization: mean age 38.8years (±7.3). 22 (23%) on CDC-stage C. Median CD4 cell count 355/μL (range: 283-416). Median HIV RNA level<50 (<50–1300).76 (80%) on HAART at the time of immunization.
Measles							
Moss, 2007	Edmonston-Zagreb measles vaccine strain (BernaBiotec)	1 dose	Children	36 18	Modified plaque reduction neutralization assay, ≥120 mUI/mL	15 months, 62% 27 months, 49%	At the time of immunization: mean age 9 months.51% were stunted. 18% had CD4% <15% and 24% ≥25%.
Melvin, 2003	MMR (M-M-R II, Merck)	2 doses	Children	11	Enzyme immunoassay at the Nichols Institute (San Juan Capistrano, CA), >1.10 ISR	12 months, 73%	First course of immunization in the first months of life before the start of HAART. Children with undetectable measles antibody levels were included in the study and revaccinated. At study entry, median age 7 years (range: 3 to 14), median time on HAART 20 months (range: 8–37), median quantitative HIV-1 levels 1.7log (range: 1.7–4.8), medianCD4T-cell number and percentage 944 cells/mm ³ (range: 397-3900)and 35% (range: 20–54). Before the initiation of HAART, 11 children were classified as immune category 3, 4 as immune category 2, and 4 as immune category 1.
Bekker, 2006	MMR	1 or 2 doses	Children	35	Enzyme immunoassay (Virotech, Ru''sselsheim, Germany), ≥ 9.0AU	84 months, 60%	First course of immunization in the first months of life. Included in the study at the start of HAART. At study entry: mean age 4.3 years (IQR: 1.4-8.8).24 (41%) on CDC-stage C and none on HAART. Follow-up during 4 years after the start of HAART.

Author, year	Vaccine	Vaccine scheme	Age class	Responders (N)	Assay used, protective titer	Time from last vaccine dose, percentage above protective titer among initial responders	Clinical and immuno-virological data at study entry
Brunell, 1995	MMR or MMRV	1 or 2 doses	Children	14	ELISA, ≥ 42	66 months, 71%	Immunized between 14 and 42 months of age. Included in the study at the mean age of 5.5 years (range: 1.5 to 9). 1 (6%) on CDC-stage C at study entry. Median CD4 cell count 934/ μ L (range: 183-1,675).
Fowlkes, 2011	Edmonston-Zagreb measles vaccine strain (Berna Biotech, formerly Swiss Serum and Vaccine Institute)	2 doses at ages 6 and 9 months	Children	23	Commercially available indirect IgG EIA (Trinity Biotech) or PRN assay, ≥ 120 mIU/mL	15 months, 73%	Mean age 6 months. 35% were stunted at birth and 22 (85%) at 18 months of age.
Tetanus toxoid							
Barbi, 1992	DTP	2 or 3 doses of primary tetanus immunization series	Children	9	Passive haemagglutination method (Tetan Test; Istituto Sieroterapico Milanese, Milan Italy) $\geq 1:1024$	16 months, 67%*	Children included at birth.
Ching, 2007	DTP	5 doses of primary tetanus immunization series + 1 booster dose of TT of 5 flocculation units (Lf/mL, Aventis Pasteur Inc., Swiftwater, PA)	Children	12	EIA Kit (BINDAZYME, The Binding Site Ltd. Birmingham, UK), ≥ 0.15 IU/mL	11.8 months, 85%*	First course of immunization in the first months of life. Included in the study at the median age of 12.6 years and received a booster dose of TT at inclusion. All on HAART at study entry. Median time on HAART: 5.3 years (range: 1.4 to 6.2). Complete responders to HAART (n=7): HIV viral load <2.6 log and CD4 819/ μ L. Incomplete responders (n=8): HIV viral load 3.7 log and CD4 429/ μ L.
Melvin, 2003	Diphtheria-tetanus-acellular-pertussis (Tripebia/Pasteur Mérieux Connaught, <7 years), or tetanus-diphtheria (Lederle Labs, ≥ 7 years)	Standard practices	Children	7	Enzyme immunoassay at Specialty Laboratories (Santa Monica, CA), >0.1IU/mL	12 months, 86%*	<i>cf; supra</i>
Rigaud, 2008	Age-appropriate tetanus toxoid (TT) vaccine in the form of DTaP, Td, or DT vaccines (originally obtained from Wyeth-Ayerst and later from Aventis-Pasteur)	3 doses at M0-M2-M4	Children	31	TetanusIgG ELISA kit (RE56901; IBL Immuno Biological Laboratories), >0.1 IU/mL	12 months, 90%*	Immunized with a 5 doses of primary tetanus immunization series in the first months of life. Included in the study at the median age of 13 years (range: 3 to 17) and received 3 booster doses of TT at study entry. At study entry, median CD4 cell count 96/ μ L (range: 5 to 636), median HIV RNA 4.8 log (range: 2.6 to 6.6).

* For tetanus vaccine, no study specifically detailed the outcome of initial responders alone, then overall rates of seroprotection are presented

7. Table 2: Selected reports on persistence of antibody levels after vaccination in healthy individuals

	Study population	Time from last vaccine dose, percentage above protective titer
HEPATITIS B		
Zanetti, Lancet 2005	Children (n=1212)	10 years, 64%
	Adolescents (n=446)	10 years, 90%
Duval, Pediatr Infect Dis J 2005	Children (n=573)	5 years, 82-87%
Alavian, Eur J Gastroenterol Hepatol 2008	Adults (n=83)	16 years, 81%
HEPATITIS A		
Van Herck, J Med Virol 2004	Adults (n=31)	12 years, 100%
Van Herck, Int J Infect Dis 2004	Adults (n=307)	10 years, 100%
Werzberger, 32 nd National Immunization Conference, 1998	Children (n=549)	5-6 years, 99%
Van Damme, Lancet 2003	Mathematical models of antibody decline estimate that protective levels of anti-HAV could be present for >25 years in adults and >14–20 years in children.	
MEASLES		
LeBaron, Arch Pediatr Adolesc Med 2007	Children (n=364)	10 years, 100%
Davidkin, J Infect Dis 2008	Children (n=183)	15 years, 95%
MUMPS		
LeBaron, J Infect Dis 2009	Children (n=144)	12 years, 95%
Davidkin, J Infect Dis 2008	Children (n=183)	15 years, 74%
RUBELLA		
LeBaron, J Infect Dis 2009	Children (n=144)	12 years, 90%
Davidkin, J Infect Dis 2008	Children (n=183)	15 years, 100%
DIPHTERIA		
Carlsson Pediatr Infect Dis J 2002	Children (n=180)	5.5 years, 76-89%
Poovorawan, Vaccine 2008	Children (n=48)	10 years, 95%
TETANUS		
Carlsson Pediatr Infect Dis J 2002	Children (n=180)	5.5 years, 93%
Poovorawan, Vaccine 2008	Children (n=48)	10 years, 100%

	Study population	Time from last vaccine dose, percentage above protective titer
POLIO		
Carlsson <i>Pediatr Infect Dis J</i> 2002	Children (n=180)	5.5 years, 96-99%
PERTUSSIS		
Poovorawan, <i>Vaccine</i> 2008	Children (n=48)	10 years, 78%
PNEUMOCOCCAL POLYSACCHARIDE VACCINE		
Musher, <i>Hum Vaccin</i> 2011	Adults	For most serotypes, antibodies persist above the levels of vaccine-naïve subjects for 5-6 years after 2 doses of PPV.
Musher, <i>JID</i> 2010		
Heidelberger, <i>J Immunol</i> 1950		
Jackson, <i>JAMA</i> 1999		
PNEUMOCOCCAL CONJUGUATE VACCINE		
Ekström, <i>Clin Vaccine Immunol</i> 2013	Children	After four years, antibody levels decline but remain higher than in the non-immunized children after 2 doses of PCV.
Schuerman, <i>Vaccine</i> 2007		
HAEMOPHILUS INFLUENZAE B		
Carlsson <i>Pediatr Infect Dis J</i> 2002	Children (n=180)	5.5 years, 97%
VARICELLA		
Kuter <i>Pediatr Infect Dis J</i> 2004	Children (n=277)	9 years, 100%
Asano <i>Pediatrics</i> 1985	Children (n=38)	7-10 years, 97%
Watson <i>J Infect Dis</i> 1995	Children (n=25)	20 years, 100%
YELLOW FEVER		
Groot Bull <i>World Health Organ</i> 1962	Adults and Children (n=108)	17 years, 97%
Niedrig <i>Trop Med Int Health</i> 1999	Adults and Children (n=209)	>10 years, 75%
JAPANESE ENCEPHALITIS		
Schuller <i>Vaccine</i> 2008	Adults (n=181)	3 years, 85%
Dubischar-Kastner <i>Vaccine</i> 2010	Adults (n=116)	2 years, 48%

8. Studies that were excluded from meta-analysis and primary reason for exclusion (n=35)

Abzug MJ, Warshaw M, Rosenblatt HM, *et al.* Immunogenicity and immunologic memory after hepatitis B virus booster vaccination in HIV-infected children receiving highly active antiretroviral therapy. *J Infect Dis* 2009; **200**: 935–46.

Outcome of initial responders not detailed

Abzug MJ, Pelton SI, Song L-Y, *et al.* Immunogenicity, safety, and predictors of response after a pneumococcal conjugate and pneumococcal polysaccharide vaccine series in human immunodeficiency virus-infected children receiving highly active antiretroviral therapy. *Pediatr Infect Dis J* 2006; **25**: 920–9.

Pneumococcal vaccine

Abzug MJ, Song L-Y, Fenton T, *et al.* Pertussis booster vaccination in HIV-infected children receiving highly active antiretroviral therapy. *Pediatrics* 2007; **120**: e1190–1202.

Too few data to allow meta-analysis

al-Attar I, Reisman J, Muehlmann M, McIntosh K. Decline of measles antibody titers after immunization in human immunodeficiency virus-infected children. *Pediatr Infect Dis J* 1995; **14**: 149–51.

Retrospective study

Belaunzarán-Zamudio PF, García-León ML, Wong-Chew RM, *et al.* Early loss of measles antibodies after MMR vaccine among HIV-infected adults receiving HAART. *Vaccine* 2009; **27**: 7059–64.

Outcome of initial responders not detailed

Falcó V, Jordano Q, Cruz MJ, *et al.* Serological response to pneumococcal vaccination in HAART-treated HIV-infected patients: one year follow-up study. *Vaccine* 2006; **24**: 2567–74.

Pneumococcal vaccine

Farquhar C, Wamalwa D, Selig S, *et al.* Immune responses to measles and tetanus vaccines among Kenyan human immunodeficiency virus type 1 (HIV-1)-infected children pre- and post-highly active antiretroviral therapy and revaccination. *Pediatr Infect Dis J* 2009; **28**: 295–9.

Retrospective study

Fernandes SJ, Shlessarenko N, Souto FJD. Effects of vertical HIV infection on the persistence of anti-HBs after a schedule of three doses of recombinant hepatitis B vaccine. *Vaccine* 2008; **26**: 1032–7.

Retrospective study

Gibb D, Giacomelli A, Masters J, *et al.* Persistence of antibody responses to Haemophilus influenzae type b polysaccharide conjugate vaccine in children with vertically acquired human immunodeficiency virus infection. *Pediatr Infect Dis J* 1996; **15**: 1097–101.

Too few data to allow meta-analysis

Glaser JB, Volpe S, Aguirre A, Simpkins H, Schiffman G. Zidovudine improves response to pneumococcal vaccine among persons with AIDS and AIDS-related complex. *J Infect Dis* 1991; **164**: 761–4.

Pneumococcal vaccine

Hung C-C, Chang S-Y, Su C-T, *et al.* A 5-year longitudinal follow-up study of serological responses to 23-valent pneumococcal polysaccharide vaccination among patients with HIV infection who received highly active antiretroviral therapy. *HIV Med* 2010; **11**: 54–63.

Pneumococcal vaccine

Kemper CA, Zolopa AR, Hamilton JR, Fenstersheib M, Bhatia G, Deresinski SC. Prevalence of measles antibodies in adults with HIV infection: possible risk factors of measles seronegativity. *AIDS* 1992; **6**: 1321–5.

Retrospective study

King JC Jr, Vink PE, Chang I, *et al.* Antibody titers eight months after three doses of a five-valent pneumococcal conjugate vaccine in HIV and non-HIV-infected children less than two years of age. *Vaccine* 1998; **16**: 361–5.

Pneumococcal vaccine

Kroon FP, Van Dissel JT, Ravensbergen E, Nibbering PH, Van Furth R. Enhanced antibody response to pneumococcal polysaccharide vaccine after prior immunization with conjugate pneumococcal vaccine in HIV-infected adults. *Vaccine* 2000; **19**: 886–94.

Pneumococcal vaccine

Levin MJ, Gershon AA, Weinberg A, Song L-Y, Fentin T, Nowak B. Administration of live varicella vaccine to HIV-infected children with current or past significant depression of CD4(+) T cells. *J Infect Dis* 2006; **194**: 247–55.

Too few data to allow meta-analysis

Lu C-L, Hung C-C, Chuang Y-C, *et al.* Comparison of serologic responses to vaccination with one dose or two doses of 7-valent pneumococcal conjugate vaccine in HIV-infected adult patients. *Vaccine* 2012; **30**: 3526–33.

Pneumococcal vaccine

Madhi SA, Adrian P, Kuwanda L, *et al.* Long-term immunogenicity and efficacy of a 9-valent conjugate pneumococcal vaccine in human immunodeficient virus infected and non-infected children in the absence of a booster dose of vaccine. *Vaccine* 2007; **25**: 2451–7.

Pneumococcal vaccine

Madhi SA, Klugman KP, Kuwanda L, Cutland C, Käyhty H, Adrian P. Quantitative and qualitative anamnestic immune responses to pneumococcal conjugate vaccine in HIV-infected and HIV-uninfected children 5 years after vaccination. *J Infect Dis* 2009; **199**: 1168–76.

Pneumococcal vaccine

Mascart-Lemone F, Gérard M, Libin M, *et al.* Differential effect of human immunodeficiency virus infection on the IgA and IgG antibody responses to pneumococcal vaccine. *J Infect Dis* 1995; **172**: 1253–60.

Pneumococcal vaccine

Nielsen H, Kvinesdal B, Benfield TL, Lundgren JD, Konradsen HB. Rapid loss of specific antibodies after pneumococcal vaccination in patients with human immunodeficiency virus-1 infection. *Scand J Infect Dis* 1998; **30**: 597–601.

Pneumococcal vaccine

Pacanowski J, Lacombe K, Campa P, *et al.* Plasma HIV-RNA is the key determinant of long-term antibody persistence after Yellow fever immunization in a cohort of 364 HIV-infected patients. *J Acquir Immune Defic Syndr* 2012; **59**: 360–7.

Retrospective study

Pensiero S, Cagigi A, Palma P, *et al.* Timing of HAART defines the integrity of memory B cells and the longevity of humoral responses in HIV-1 vertically-infected children. *Proc Natl Acad Sci USA* 2009; **106**: 7939–44.

Retrospective study

Pessoa SD, Miyamoto M, Ono E, Gouvêa AFTB, De Moraes-Pinto MI, Succi RCM. Persistence of vaccine immunity against hepatitis B virus and response to revaccination in vertically HIV-infected adolescents on HAART. *Vaccine* 2010; **28**: 1606–12.

Retrospective study

Peters VB, Sood SK. Immunity to Haemophilus influenzae type b after reimmunization with oligosaccharide CRM197 conjugate vaccine in children with human immunodeficiency virus infection. *Pediatr Infect Dis J* 1997; **16**: 711–3.

Outcome of initial responders not detailed

Powis JE, Raboud J, Ostrowski M, Loutfy MR, Kovacs C, Walmsley SL. The recombinant hepatitis B surface antigen vaccine in persons with HIV: is seroconversion sufficient for long-term protection? *J Infect Dis* 2012; **205**: 1534–8.

Retrospective study

Puthanakit T, Aурpibul L, Yoksan S, Sirisanthana T, Sirisanthana V. A 3-year follow-up of antibody response in HIV-infected children with immune recovery vaccinated with inactivated Japanese encephalitis vaccine. *Vaccine* 2010; **28**: 5900–2.

Too few data to allow meta-analysis

Rodriguez-Barradas MC, Groover JE, Lacke CE, *et al.* IgG antibody to pneumococcal capsular polysaccharide in human immunodeficiency virus-infected subjects: persistence of antibody in responders, revaccination in nonresponders, and relationship of immunoglobulin allotype to response. *J Infect Dis* 1996; **173**: 1347–53.

Pneumococcal vaccine

Siberry GK, Collier RJ, Henkle E, *et al.* Antibody response to hepatitis A immunization among human immunodeficiency virus-infected children and adolescents. *Pediatr Infect Dis J* 2008; **27**: 465–8.

Outcome of initial responders not detailed

Siriaksorn S, Puthanakit T, Sirisanthana T, Sirisanthana V. Prevalence of protective antibody against hepatitis B virus in HIV-infected children with immune recovery after highly active antiretroviral therapy. *Vaccine* 2006; **24**: 3095–9.

Retrospective study

Spoulou VI, Tsoumas DL, Papaevangelou VG, Mostrou GI, Theodoridou MC. Immunogenicity and immunological memory induced by a 7-valent pneumococcal CRM197 conjugate vaccine in symptomatic HIV-1 infected children. *Vaccine* 2005; **23**: 5289–93.

Pneumococcal vaccine

Talesnik E, Vial PA, Labarca J, Méndez C, Soza X. Time course of antibody response to tetanus toxoid and pneumococcal capsular polysaccharides in patients infected with HIV. *J Acquir Immune Defic Syndr Hum Retrovirol* 1998; **19**: 471–7.

Pneumococcal vaccine

Tattevin P, Depatureaux AG, Chapplain JM, *et al.* Yellow fever vaccine is safe and effective in HIV-infected patients. *AIDS* 2004; **18**: 825–7.

Retrospective study

Tejiokem MC, Gouandjika I, Béniguel L, *et al.* HIV-infected children living in Central Africa have low persistence of antibodies to vaccines used in the Expanded Program on Immunization. *PLoS ONE* 2007; **2**: e1260.

Retrospective study

Veit O, Niedrig M, Chapuis-Taillard C, *et al.* Immunogenicity and safety of yellow fever vaccination for 102 HIV-infected patients. *Clin Infect Dis* 2009; **48**: 659–66.

Retrospective study

Zaccarelli-Filho CA, Ono E, Machado DM, *et al.* HIV-1-infected children on HAART: immunologic features of three different levels of viral suppression. *Cytometry B ClinCytom* 2007; **72**: 14–21.

Retrospective study