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Insufficient vaccine coverage and vaccine hesitancy in people living with HIV: A prospective study in outpatient clinics in the Paris region

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ABSTRACT

Vaccine prevention strategies play a crucial role in the management of people living with HIV (PLWH). The aim of this study was to assess vaccination coverage and identify barriers to vaccine uptake in PLWH in the Paris region.

A cross-sectional survey was conducted in PLWH in 16 hospitals in the Paris region. The vaccination status, characteristics, opinions, and behaviors of participants were collected using a face-to-face questionnaire and from medical records.

A total of 338 PLWH were included (response rate 99.7 %). The median age of participants was 51 years (IQR: 41–58). Vaccination coverage was 77.3 % for hepatitis B (95 % CI: 72.3–81.8 %), 62.7 % for hepatitis A (57.3–67.9 %), 61.2 % for pneumococcal vaccines (55.8–66.5 %), 56.5 % for diphtheria/tetanus/poliomyelitis (DTP) (51.0–61.9 %), 44.7 % for seasonal influenza (39.3–50.1 %), 31.4 % for measles/mumps/rubella (26.4–36.6 %) and 38.5 % for meningococcal vaccine (13.9–68.4 %). The main reason for vaccine reluctance was related to the lack of vaccination proposals/reminders. The overall willingness to get vaccinated was 71.0 % (65.9–75.8 %). In the multivariable analysis, several factors were associated with a higher vaccine uptake; for DTP vaccine: higher education level, having vaccination records, being registered with a general practitioner; for seasonal influenza vaccine: age > 60 years, higher education level, being employed.

The overall vaccination coverage was suboptimal. Development of strategies reducing missed opportunity to offer vaccines is needed.

Abbreviations: aPRR, adjusted PRR; CI, confidence interval; DTP, diphtheria/tetanus/poliomyelitis; GP, general practitioner; HCSP, French High Council for Public Health; HIV, human immunodeficiency virus; HPV, human papillomavirus; IQR, interquartile range; MMR, measles/mumps/rubella; MSM, men who have sex with men; PCV13, pneumococcal conjugate vaccine; PLWH, people living with HIV; PPV23, 23-valent polysaccharide pneumococcal vaccine; PRR, prevalence rate ratio; WHO, World Health Organization.

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1. Introduction

Human immunodeficiency virus (HIV) infection may aggravate certain common vaccine-preventable infectious diseases, depending on severity of the immunodeficiency. To ensure healthy lives of people living with HIV (PLWH), the French High Council for Public Health (HCSP) has published vaccine guidelines for immunocompromised patients, including PLWH, in 2012 and updated in 2014 [1,2]. These guidelines, despite minor differences, are globally in line with worldwide vaccination guidelines [3–9].

Nearly 10 years after the publication of the guidelines, are there vaccination gaps still present?

Due to the multiplicity of stakeholders involved in the vaccination process and the plethora of vaccination registers, it is challenging to conduct vaccine studies, as no reliable sources of information are available. According to studies conducted in the United States [10] and some European countries [11–17], vaccination coverage is low among PLWH. Studies conducted in France between 2015 and 2017 have shown similar results [18–23]. In the Paris region, with more than 50 hospitals and a third of French PLWH followed (Institut de Veille Sanitaire 2014), no data on vaccination practices is available. Nevertheless, it can be assumed that vaccination coverage does not meet the targets and could be improved.

This raises the question of what are the barriers to achieve satisfactory vaccination coverage. Patients may not be vaccinated due to misinformation or misperception of vaccines by themselves, or even by their physicians. Identifying the determinants associated with incomplete vaccination schedule in PLWH could help improve vaccination adherence, and thus the vaccination coverage.

Therefore, the aim of this study was to assess the vaccination status in PLWH in the Paris region, as well as to identify common factors associated with non-vaccination and the influence of vaccination promotion on patients and caregivers. The results of this study could help physicians optimize the follow-up of PLWH.

As the design of this study was made before the COVID-19 pandemic onset, COVAVIH did not cover COVID-19 vaccines. It should be noted, that while early studies reported conflicting results, recent evidence suggests, that HIV infection itself, comparing to general population, does not increase the adverse outcomes of SARS CoV2 infections [24]. Moreover, vaccines against SARS CoV2 show favorable immunogenicity and efficacity in PLWH, especially after booster dose [25], which can be administered simultaneously with other vaccines [26]. Information about opinions on vaccines against SARS CoV2 and vaccination coverage could be provided subsequently, in the second phase study results.

2. Methods

2.1. Study setting

The COVAVIH study was a cross-sectional survey conducted on a random sample of PLWH in 16 hospitals in the Paris region between February 2020 and April 2021. Inclusion criteria were: patients followed for HIV infection for at least 6 months, aged over 18 years and with a CD4 cell count $> 200/mm^3$. Patients treated with chemotherapy or immunosuppressive drugs during the study period were excluded.

Among eligible 339 PLWH, obtained through systematic sampling in participating hospitals on selected days, with 1 in 5 patients for each consulting physician, 338 were included. This stands for 99.7 % response rate. Written informed consent was obtained from all participants.

Participants' baseline characteristics were collected using a self-administered questionnaire and a face-to–face questionnaire, and included age, gender, country of birth, marital status, number of dependent children, education level, occupation, smoking status, having a vaccination record and having a social compulsory health insurance. Vaccination coverage for the following vaccines recommended by the HCSP was collected: measles/mumps/rubella vaccine (MMR), diphtheria/tetanus/poliomyelitis vaccine (DTP), seasonal influenza vaccine, pneumococcal vaccines, hepatitis B vaccine, hepatitis A vaccine and meningococcal group C vaccine. HIV infection characteristics were extracted from medical records: HIV transmission mode, date of diagnosis of HIV infection, HIV disease stage, last CD4 count, CD4 nadir and last HIV plasma viral load. Willingness to get vaccinated and the main reasons for not being vaccinated were also collected (see Fig. 1).

The Comité de Protection des Personnes (CPP) Ile de France III (French ethics committee) issued a favorable approval for the study conduct on November 19, 2019 (CPP reference: 3747-NI, ID-RCB: 2019-A02692-55).

It should be noted that in March 2020, to limit the spread of COVID-19 pandemic, non-urgent visits of PLWH had to be postponed. The study was therefore temporarily interrupted in the eighteen hospitals that had not yet started inclusions, out of twenty that agreed to participate. The study was resumed in October 2020. However, four hospitals withdrew from the study due to limited human resources. Nevertheless, the representativeness of the population was maintained [27]. As a consequence, for influenza vaccine, we considered as vaccinated those, who received the vaccine during ongoing season, at the time of the study in each center, for two hospitals in 2019/2020, and for the others in 2020/2021.

2.2.

The latest HCSP guidelines (2014) [2] for PLWH recommend the following vaccines: MMR vaccine, DTP vaccine, seasonal influenza vaccine, pneumococcal vaccines, hepatitis B vaccine, hepatitis A vaccine and meningococcal group C vaccine. Patients were considered appropriately vaccinated if they had received two doses of MMR vaccine, one dose of DTP vaccine within the last 10 years, an annual influenza vaccine, one dose of pneumococcal conjugate vaccine (PCV13) followed by at least one dose of the 23-valent polysaccharide pneumococcal vaccine (PPV23), the last dose having been received no more than five years earlier, four double doses of hepatitis B vaccine, two doses of hepatitis A vaccine and one dose of the meningococcal group C conjugate vaccine if they were aged under 24. Yellow fever vaccination coverage was not investigated, since yellow fever vaccine is only recommended in French Guiana. Human papillomavirus (HPV) vaccination coverage was not assessed. Vaccination coverage for MMR, DTP, seasonal influenza, pneumococcus, hepatitis B and hepatitis A was assessed in the whole population. Participants for whom hepatitis A vaccine was not indicated were classified as with complete hepatitis A vaccination schedule, as in the Bordeaux study [20]. For meningococcal vaccines, vaccination status was estimated only in participants for whom vaccination was indicated, as in the Grenoble study [21]. Moreover, hepatitis B surface antibody titers were collected from medical records to define participants' hepatitis B status. All participants received information on vaccination and a leaflet on vaccination in PLWH. For those whose vaccination was incomplete a vaccination was advised. In the absence of a vaccination record, the vaccination status was considered negative.

2.3. Statistical analysis

The main outcome of the COVAVIH study was the vaccination coverage for each vaccine recommended by the HCSP for PLWH, assessed by a physician during a routine outpatient consultation, through analysis of available medical records. No weighting was applied to the survey data.

Vaccination coverage was treated as a dichotomous variable, with individuals classified as either vaccinated or unvaccinated for each vaccine examined. Vaccination coverage was described by the percentage of people vaccinated and their 95 % confidence intervals (CIs), calculated using the Clopper-Pearson exact method. The baseline

characteristics and the vaccination coverage were analyzed by estimating the prevalence rate ratios (PRR) and adjusted PRR (aPRR), the most appropriated measures of association in a cross-sectional study. Univariate and multivariable general linear models (Poisson regression) were then used. For the multivariable analyzes according to the vaccine and for all vaccines combined, covariates with a P-value < 0.05 and clinically relevant were retained. In the univariate analyzes, a P-value < 0.05 was considered significant. The reasons for not being vaccinated were presented with their percentage and 95 % confidence intervals. Statistical analyzes were performed using SAS software (version 9.4).

3. Results

3.1. Characteristics of surveyed participants

A total of 338 eligible participants were included in the study. Their baseline characteristics are summarized in Table 1. The mean age was 49.9 years (median: 51.0 years; IQR: 41.0–58.0 years). Sixty-five percent of participants were male. Only one in two participants was born in France. One participant in 3 was born in sub-Saharan Africa. HIV infection was diagnosed before 2013 in 250 participants (74.0 %). A heterosexual transmission was reported in 170 participants (50.3 %), while 113 participants (33.4 %) were men having sex with men (MSM). The last CD4 cell count was $\geq 500/mm^3$ in 240 participants (71.0 %). The plasma HIV viral load was < 50 copies/mL in 316 participants (93.5 %).

3.2. Vaccination coverage

The vaccination coverage for each vaccine is shown in Fig. 2. The highest vaccination coverage rates were observed for hepatitis B (245/317; 77.3 %; 95 % CI: 72.3–81.8 %), hepatitis A (212/338; 62.7 %; 95 % CI: 57.3–67.9 %) and pneumococcal vaccines (207/338; 61.2 %; 95 % CI: 55.8–66.5 %). A low vaccine coverage was observed for DTP (191/338; 56.5 %; 95 % CI: 51.0–61.9 %), seasonal influenza (151/338; 44.7 %; 95 % CI: 39.3–50.1 %) and MMR (145/338; 31.4 %; 95 % CI: 26.4–36.6 %) vaccines. Meningococcal vaccination coverage, assessed in participants under 24 years, was 5/13 (38.5 %; 95 % CI: 13.9–68.4 %).

The univariate analyses of vaccination coverage for each vaccine are presented in Table 1. The DTP vaccination coverage was higher: in men and transgender participants (61.0 %) vs. female (48.3 %), in participants who had been to school (65.0 %) vs. those who had never been to school (9.1 %), in MSM (63.7 %) vs. heterosexual (50.0 %), in participants who were in a relationship (66.7 %) vs. in singles (38.5 %), having compulsory health insurance (66.2 %) vs. in those not having one (37.9 %), who were registered with a general practitioner (GP) (70.6 %.) vs. those who were not (39.1 %). Those who were born in sub-Saharan Africa were less likely to be up to date with their DTP vaccination (40.3 %) than those born in France (60.1 %). Regarding the MMR vaccine, a detectable plasma HIV viral load was associated with a higher vaccine coverage (last HIV viral load <=50 copies/mL 76.9 % vs. > 50 copies/mL 84.2 %). Hepatitis B vaccine coverage was lower in participants who were not in a relationship (70.8 %) vs. singles (80.9 %). MSM were more likely to be vaccinated against hepatitis A (74.4 %) than heterosexual participants (57.1 %). As for the seasonal influenza vaccine, vaccination coverage was higher in participants aged over 60 (68.4 %) vs. under 60 (37.4 %), in men and transgender participants (50.9 %) vs. female (33.3 %). Again, participants born in sub-Saharan Africa (29.8 %) were less likely to be vaccinated against seasonal influenza than those born in France (52.9 %). A lower pneumococcal vaccine uptake was found in participants with no vaccination record (55.8 %) vs. in those having one (66.5 %) and in those with detectable plasma HIV viral load (last HIV viral load <=50 copies/mL 62.7 % vs. > 50 copies/mL 40.9 %).

3.3. Willingness to get vaccinated and main reasons for not being vaccinated

Table 2 shows the reasons for which participants did not vaccinate. All participants considered the vaccines to be effective and were aware of their full reimbursement. Among the reasons for not being up to date with the following vaccines, the fear of injections was mentioned: pneumococcal (42.0 %; 95 % CI: 33.4–50.9 %), seasonal influenza (32.6 %; 95 % CI: 26.0–39.8 %), hepatitis A (27.8 %; 95 % CI: 20.2–36.5 %), hepatitis B (25.0 %; 95 % CI: 15.5–36.6 %), MMR (22.0 %; 95 % CI: 16.8–27.9 %), and DTP (19.1 %; 95 % CI: 13.0–26.3 %) vaccines. Some patients were convinced that vaccines were contraindicated for them, while others doubted their usefulness. Almost no participant believed in the harmfulness of vaccines. All participants who considered themselves unvaccinated, reported that they had never been offered a vaccine uptake. All these participants were subsequently encouraged to get vaccinated.

Among participants with incomplete vaccine schedule, 240/338 (71.0 %; 95 % CI: 65.9–75.8 %) were overall willing to get vaccinated. Nevertheless, among participants with incomplete vaccination coverage, the reported willingness to vaccinate for each vaccine separately was lower: 12.5 % for meningococcal vaccine, 22.2 % for hepatitis B vaccine, 23.7 % for MMR vaccine, 26.7 % for seasonal influenza vaccine, 27.9 % for DTP vaccine, 30.2 % for hepatitis A vaccine, and 44.3 % for pneumococcal vaccines.

Choose the most suitable one for each vaccine

Do you think your vaccination schedule is complete for the following vaccines?	Diphtheria-Tetanus-Whooping Cough	Measles, Mumps, Rubella	Hepatitis B	Hepatitis A	Pnemococcus	Seasonal Influenza	Méningococcus C	
Yes								
No								
I don't know								

If you think that your vaccination schedule is incomplete, what would be the reason of that?
YES (1) NO (2) I DON'T KNOW (5)

Reasons	You are afraid of injections	You think having a contraindication	You think it is not useful	You think it is dangerous	You think it can make sick/ill	You think it does not work	You think it is not reimbursed	The vaccine has not been offered to me
Diphtheria-Tetanus-Whooping Cough								
Measles, Mumps, Rubella								
Hepatitis B								
Hepatitis A								
Pnemococcus								
Seasonal Influenza								
Méningococcus C								

QF3: **In general, would you like to get vaccinated if your vaccination schedule is not complete?**

Yes (1) ☐ No (2) ☐

QF4: **If you have chosen « YES » in the question QF3, which of the following vaccines would you like to get?**

Diphtheria-Tetanus-Whooping Cough (1) ☐ Measles-Mumps-Rubella (2) ☐
Hepatitis B (3) ☐ Hepatitis A (4) ☐
Pneumococcus (5) ☐ Seasonal Influenza (6) ☐
Meningococcus C (7) ☐

QF5: **If you have chosen « YES » in the question QF3, what would be the main reason for your decision?**

You think they are useful (1) ☐
You think they are efficacious (2) ☐
You think they are reimbursed (3) ☐
You think that one day you can catch these diseases (4) ☐
Your doctor has convinced you to get vaccinated (5) ☐

QF6: **If you have chosen « NO » in the question QF3, which of the following vaccines would you not like to get?**

Diphtheria-Tetanus-Whooping Cough (1) ☐ Measles-Mumps-Rubella (2) ☐
Hepatitis B (3) ☐ Hepatitis A (4) ☐
Pneumococcus (5) ☐ Seasonal Influenza (6) ☐
Meningococcus C (7) ☐

Fig. 1. Survey questions. The figure presents self-administered survey questions concerning reasons, in their opinions, for not being vaccinated, and their willingness to get vaccines.

Table 1
Factors associated with non-vaccination. Proportions and determinants of vaccination coverage among participants. Statistically significant results are shown in light grey.

Background characteristics[b]	Sample size	DTP			MMR			Hepatitis B			Hepatitis A			Seasonal Influenza			Pneumococcal vaccines		
	n (%)	n (%)	IC%95		n (%)	IC%95		n (%)	IC%95		n (%)	IC%95		n (%)	IC%95		n (%)	IC%95	
		191 (56.5 %)			145 (42.9 %)			245 (77.3 %)			212 (62.7 %)			151 (44.7 %)			207 (61.2 %)		
Age group	76	%)49	%	%	%)17	13.1	32.2	%)53	55.6	77.3	41	40.4	63.3	[a]99	54.3	76.1	%)49	50.4	72.7
<60 years	(22.5)	(64.5	50.4	72.7	(22.4			(73.6			(54.0			(37.8			(64.5		
≥60 years		%)	%	%	%)			%)			%)			%)52 (68.4 %)			%)		
Gender	5)218	[a]58	%	%	8 %)	25.5	38.3	4 %)	66.5	78.7	3 %)	58.4	71.4	[a]40	44.1	57.7	2 %)	55.6	68.8
Female	(64.5)	(48.3	54.2	67.5	69			159			142			(33.3			136		
Men and transgender		%) 133 (61.0 %)	%	%	(31.6 %)			(78.3 %)			(67.0 %)			%) 111 (50.9 %)			(62.4 %)		
Geographical origin	114 (33.7)	[a]92 (60.1	% 31.3	% 49.9	%)31 (27.2	19.3 13.820.5	36.3 50.249.9	%)79 (77.5	60.0 53.757.2	77.6 88.985.0	%)68 (59.7	50.1 42.454.8	68.7 80.683.2	*81 (52.9	21.6 38.830.4	39.1 77.661.2	%)67 (58.8	49.2 38.850.1	67.9 77.679.5
Metropolitan France	27 (8.0)	%)46 (40.3	% 49.8	% 86.2	%)8 (29.6			%)20 (80.0			%)17 (63			%)34 (29.8			%)16 (59.3		
Sub-Saharan Africa	44 (13.0)	%)19 (70.4	% 62.2	% 88.5	%)15 (34.1			%)32 (74.4			%)31 (70.5			%)16 (59.3			%)29 (65.9		
North Africa and Middle East		%)34 (77.3	%	%	%)			%)			%)			%)20 (45.5			%)		
Other		%)												%)					
Education	20 (5.9)	[a]5	%	%	%)5	8.7	49.1	%)15	50.9	91.3	%)10	27.2	72.8	[a]3	36.1	80.9	%)13	40.8	84.6
Never went to school	126 (37.3)	(9.1 %)14	45.7 %	88.1 %	(25.0 %)40	23.723.1	40.639.1	(83.3 %)91	63.568.7	79.883.4	(50.0 %)75	50.461.7	68.277.6	(5.5 %)12	39.446	57.563.3	(65.0 %)79	53.650.4	71.167.4
Primary school	137 (40.5)	(70.0 %)83	56.9 %	74.1 %	(31.8 %)42			(75.8 %) 105			(59.5 %)96			(60.0 %)61			(62.7 %)81		
Secondary school		(65.9 %)89	56.4 %	72.9 %	(30.7 %)			(80.2 %)			(70.1 %)			(48.4 %)75			(59.1)		
Higher education		(65.0)												(54.7 %)					
Work	52 (15.4)	[a]126 (67.7	% 50.9	% 78.0	%)18 (34.6	22.0 20.4	49.1 38.9	%)39 (76.5	61.1 59.0	86.0 77.9	[a]123 (66.1	35.8 52.8	64.2 72.4	[a]93 (50	56.9 13.5	82.9 30.3	%)36 (69.2	54.9 47.7	81.3 67.8
Employed	100 (29.6)	%)34 (65.4	% 22.1	% 41.0	%)29 (29.0			%)69 (76.7			%)26 (50.0			%)37 (71.2			%)58 (58.0		
Unemployed		%)31 (31.0 %)	%	%	%)			%)			%)63 (63 %)			%)21 (21.0 %)			%)		
Other																			
Type of income	%)32	%)21	%	%	%)10	16.120.2	50.043.3	%)24	56.647.7	88.572.0	%)21	46.846.2	81.470.6	%)20	43.73.3	78.918.2	%)20	43.743.3	78.967.9
Salary	(9.5 %)	(65.6	46.8	81.4	(31.3			(82.8			(65.6			(62.5			(62.5		
Social community benefits	68 (20.1 %)	%)12 (17.6 %)	% 9.5 %	% 28.8 %	%)21 (30.9 %)			%)41 (68.3 %)			%)40 (58.8 %)			%)6 (8.8 %)			%)38 (55.9 %)		
Other																			
In a relationship	%)122	[a]144	%	%	%)34	20.1	36.7	[a]165	56.4	73.9	%)69	47.3	65.5	*108	26.8	44.4	%)76	53.1	70.9
Yes	(36.1 %)	(66.7 %)47	29.9 %	47.8 %	(27.9 %)			(80.9 %)80			(56.6 %)			(50.0 %)43			(62.3 %)		
No		(38.5 %)						(70.8 %)						(35.3 %)					

(*continued on next page*)

Table 1 (*continued*)

Background characteristics[b]	Sample size	DTP			MMR			Hepatitis B			Hepatitis A			Seasonal Influenza			Pneumococcal vaccines		
	n (%)	n (%)	IC%95		n (%)	IC%95		n (%)	IC%95		n (%)	IC%95		n (%)	IC%95		n (%)	IC%95	
		191 (56.5 %)			145 (42.9 %)			245 (77.3 %)			212 (62.7 %)			151 (44.7 %)			207 (61.2 %)		
Private health insurance policy	%)116 (34.3 %)	[a]147 (66.2 %)	% 29.1 %	% 47.4 %	%)34 (39.3 %)	21.2	38.5	%)78 (76.5 %)	57.9	75.7	%)72 (62.1 %)	52.6	70.9	%)32 (27.6 %)	19.7	36.7	%)71 (61.2 %)	51.7	70.1
Yes		%)44 (37.9 %)																	
No																			
Vaccination records	%)149 (47 %)	[a]132 (76.3 %)	% 31.7 %	% 47.9 %	%)49 (29.7 %)	25.4	41.0	%) 111 (74.5 %)	66.7	81.3	%)98 (59.4 %)	57.6	73.3	[a]95 (54.9 %)	29.8	45.9	[a]115 (66.5 %)	53.4	69.6
Yes		%)59 (35.8 %)												%)56 (33.9 %)			%)92 (55.8 %)		
No																			
HIV transmission group	(50.3 %)113 (33.4 %)55 (16.3 %)	[a]85 (50 %)72 (63.7 %)34 (61.8 %)	2 % 54.1 % 47.7 %	8 % 72.6 % 74.6 %	(31.2 %)36 (31.9 %)17 (30.9 %)	.3 23.419.1	.7 41.344.8	(73.6 %)89 (82.4 %)39 (78.0 %)	.3 70.157.1	.7 85.982.4	(57.1 %)84 (74.4 %)31 (56.4 %)	.3 65.343.3	.6 82.169.7	[a]57 (33.5 %)64 (56.6 %)30 (54.6 %)	.5 47.040.6	.2 65.968.0	(60.6 %)72 (63.7 %)32 (58.2 %)	8 54.144.1	.0 72.671.3
Heterosexual																			
MSM																			
Other																			
HIV CDC stage	%)249 (73.7 %)	%) 146 (58.6 %)	% 52.2 %	% 64.8 %	%)83 (33.3 %)	27.5	39.6	%) 180 (77.6 %)	66.3	77.8	%) 156 (62.7 %)	56.3	68.7	%) 107 (43.0 %)	36.7	49.4	%) 151 (60.6 %)	54.3	66.8
C																			
Other than C																			
Last CD4 cells count/mm^3	%)240 (71.0 %)	%) 137 (57.1 %)	% 50.6 %	% 63.4 %	%)70 (29.2 %)	23.5	35.4	%) 175 (77.8 %)	66.8	78.4	%) 147 (61.2 %)	54.8	67.4	%) 100 (41.7 %)	35.4	48.2	%) 144 (60.0 %)	53.5	66.2
<500																			
≥500																			
Last HIV viral load copies/mL	%)22 (6.5 %)	%)8 (36.4 %)	% 17.2 %	% 59.3 %	[a]94 (29.8 %)12 (54.5 %)	32.2	75.6	%)16 (84.2 %)	49.8	89.3	%)13 (59.1 %)	36.4	79.3	%)8 (36.4 %)	17.2	59.3	%)9 (40.9 %)	20.7	63.6
<=50																			
>50																			
Registered with a GP	%)151 (44.7 %)	[a]132 (70.6 %)59 (39.1 %)	% 31.2 %	% 47.3 %	%)49 (32.5 %)	25.1	40.5	%) 103 (75.7 %)	60.1	60.1	%)99 (65.6 %)	57.4	73.1	[a]102 (54.6 %)49 (32.5 %)	25.1	40.5	%)93 (61.6 %)	53.3	69.4
Yes																			
No																			
Number of medical visits with GP[c]	%)193 (57.1 %)	%) 103 (53.4 %)	% 46.1 %	% 60.6 %	%)62 (32.1 %)	25.6	39.2	%) 113 (75.1 %)	51.3	65.6	%) 117 (60.6 %)	53.3	67.6	%)85 (44.0 %)	36.9	51.3	%) 115 (59.6 %)	52.3	66.6
<5																			
5 or more																			

Abbreviations: CDC = centers for disease control and prevention; CI = Confidence Interval; DTP = diphtheria/tetanus/poliomyelitis; GP = general practitioner; HIV = human immunodeficiency virus; MMR = measles/mumps/rubella; MSM = men who have sex with men; PRR = prevalence rate ratio.

[a] Associated with vaccination coverage ($p < 0.05$).

[b] Vaccination schedule was considered complete in following situations: one dose of DTP vaccine within the last 10 years; two doses of MMR vaccine; four double doses of hepatitis B vaccine; two doses of hepatitis A vaccine; an annual influenza vaccine (2019/2020 for 2 hospitals, 2020/2021 for 14 hospitals), one dose of pneumococcal conjugate vaccine (PCV13) followed by at least one dose of the 23-valent polysaccharide pneumococcal vaccine (PPV23), the last dose having been received no more than five years earlier.

[c] With General practitioner during last 24 months.

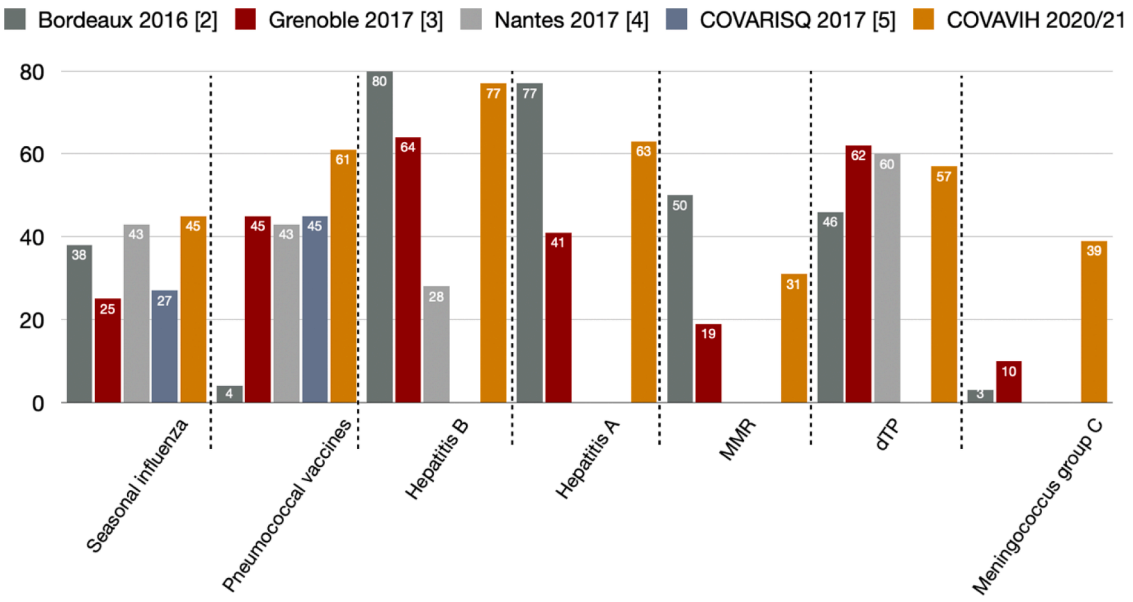

Fig. 2. Comparison of the vaccination coverage for the vaccines recommended by the HCSP in PLWH between the COVAVIH study and published French studies. The figure presents the results of four studies conducted in PLWH in Bordeaux in 2016 [20], in Grenoble in 2017 [21], in Nantes in 2017 [22], and a study of the French National Healthcare System data between 2009 and 2017 [23]. As the study conducted in Saint-Etienne in 2016 [19] only focused on the DTP status (43.9%), and the PREVAGAY study [18] conducted in HIV-seropositive MSM in Lille, Paris, Montpellier and Nice in 2015 only focused on the hepatitis B status (65.2%), to simplify the graph they were not included.

3.4. Factors associated with having complete vaccination schedule

The factors associated with having complete vaccination schedule, adjusted for each vaccine, are described in Table 3. The multivariable analysis revealed factors significantly associated with vaccination. For the DTP vaccine, associated factors included country of birth ($p = 0.0328$), education level ($p = 0.0014$), having a vaccination record ($p < 0.0001$) and being registered with a GP ($p = 0.0078$). For the seasonal influenza vaccine, the associated factors included an age > 60 years ($p = 0.0327$), high education level ($p = 0.0126$), high incomes ($p = 0.0049$). For the hepatitis A vaccine, the associated factor was HIV transmission in MSM ($p = 0.0247$).

4. Discussion

The COVAVIH study was the first multicenter study conducted in France to assess the vaccination coverage in PLWH, in the region with the highest national HIV prevalence. We analyzed the real-life vaccination coverage and obtained information on perceptions of vaccination in PLWH.

4.1. COVAVIH vaccination coverage compared to other populations

Vaccination coverage of PLWH reported in French single-center studies is fairly low [18–23], and relatively similar only for DTP, pneumococcal and seasonal influenza vaccines (see Fig. 2). The uptake of other vaccines has been described as heterogeneous. For some vaccines, particularly those targeting only a part of the PLWH population, this could be explained by the various definitions of the vaccination status. In this case, the comparison would be cumbersome, or even impossible. Furthermore, for some vaccines, obtaining reliable information on vaccination status is laborious, which could hamper research.

It should be noted that, compared to the general French population, COVAVIH study participants had a higher vaccination rate for DTP [28] and pneumococcal vaccines [29], and a lower rate for seasonal influenza vaccine [30,31]. The meningococcal vaccine status was similar in our study and in the general French population [32]. How can these significant differences be explained? Another question is why vaccine uptake is so low in France. Could this be due to local reluctance/opposition to vaccination, or to failures in the overall healthcare system?

Information on vaccination coverage in PLWH in other countries seems rather scarce and few data are available on patients from all over the world. Some results must therefore be interpreted with caution. Certainly, the absence of vaccination records could lead to an underestimation of vaccine uptake, but specific antibody testing would not be a key strategy. The decline in humoral immunity over the years could lead to an underestimation of vaccine uptake, which could explain why only around half of the Austrian population has been immunized against MMR (seropositivity, 2012–2013) [15]. Based on available data on vaccination coverage, DTP vaccine uptake appears to be fairly similar to that observed in the COVAVIH study, with rates of 50–60 % (tetanus seropositivity in Austria, 2012–2013 [14], DTP vaccination status in Brazil, 2009–2013 [33]. Considering that the World Health Organization (WHO) encourages the inclusion of the DTP vaccine in routine immunization programs for the whole population, these vaccination rates are alarmingly low.

Similarly, influenza vaccine, preventing from infection associated with significant morbidity and mortality every year, would be one of the most contested vaccines in terms of vaccine hesitancy. The persistence of a low rate of influenza vaccination, notably in the United States (1999–2008), where only 35 % of PLWH are vaccinated [10], has been reported (compared to 45 % in the COVAVIH study).

Furthermore, pneumococcal and meningococcal infections are the main causes of life-threatening bacterial diseases, while the immunization rate against these infections is very low. In Brazil [33], 23 % of PLWH had complete vaccination schedule for pneumococcal vaccines, and only 6 % for meningococcal vaccines (compared to 61 % and 39 % in the COVAVIH study, respectively).

Viral hepatitis may significantly reduce the quality of life. This is why the WHO aims to reduce new hepatitis virus infections by 90 % by 2030. Nonetheless, little progress seems to have been made in increasing hepatitis B vaccination rates. In the United Kingdom (1996–2009) [12], seroprotection against hepatitis B virus reached 58.2 %, with only 49 % of patients having received three doses of hepatitis B vaccine, and 30 % having received no dose at all (1997–2004) [13]. Similar results have been observed in Brazil [33] with 56.7 % of participants immunized

Table 2
Reasons for not being vaccinated.

Reasons for not being vaccinated	DTP vaccine		MMR vaccine		Hepatitis B vaccine		Hepatitis A vaccine		Seasonal Influenza vaccine		Pneumococcal vaccines	
	n (%)	95 % CI	n (%)	95 % CI	n (%)	95 % CI	n (%)	95 % CI	n (%)	95 % CI	n (%)	95 % CI
Fear of injections	(19.1	0–26.3	(22.0	8–27.9	(25.0	–36.6 %	(27.8	2–36.5	(32.6	0–39.8	(42 %	4–50.9
Yes	%)119	73.7–87.0	%)181	72.1–83.2	%)54	63.4–84.5	%)91	63.5–79.8	%)126	60.2–74.0	76	49.1–66.6
No	(80.9		(78.0		(75.0	%	(72.2		(67.4		(58 %)	
	%)		%)		%)		%)		%)			
Belief that vaccine is contraindicated	20	8.5–20.2	28	8.2–17.0	8 (11.1	4.9–20.7	22	11.3–25.2	25	8.8–19.1	31	16.7–31.9
	(13.6	79.8–91.5	(12.1	83.0–91.8	%)64	%	(17.5	74.8–88.7	(13.4	80.9–91.2	(23.7	68.1–83.3
Yes	%)127		%)204		(88.9	79.3–95.1	%)104		%)162		%)100	
No	(86.4		(87.9		%)	%	(82.5		(86.6		(76.3	
	%)		%)				%)		%)		%)	
Belief that vaccine is unuseful	15	5.8–16.3	30	8.9–17.9	11	7.9–25.7	24	12.6–27.0	24	8.4–18.5	21	10.2–23.5
	(10.2	83.7–94.2	(12.9	82.1–91.1	(15.3	74.3–92.1	(19.1	73.0–87.4	(12.8	81.5–91.6	(16.0	76.5–89.8
Yes	%)132		%)202		%)61		%)102		%)163		%)110	
No	(89.8		(87.1		(84.7		(80.9		(87.2		(84.0	
	%)		%)		%)		%)		%)		%)	
Belief that vaccine is dangerous	1 (0.7	0.0–3.7	0 (0.0	–	0 (0.0	–	0 (0.0	–	0 (0.0	–	0 (0.0	–
	%)146	96.3–100.0	%)232	–	%)72	–	%)126	–	%)187	–	%)131	–
Yes	(99.3		(100.0		(100.0		(100.0		(100.0		(100.0	
No	%)		%)		%)		%)		%)		%)	
Belief that vaccine can make people sick	12 (8.2	4.3–13.8	20 (8.6	5.3–13.0	5 (6.9	2.3–15.5	18	8.7–21.6	11 (5.9	3.0–10.3	18	8.4–20.8
	%)135	86.2–95.7	%)212	87.0–94.7	%)67	84.5–97.7	(14.3	78.4–91.3	%)176	89.7–97.0	(13.7	79.2–91.6
Yes	(91.8		(91.4		(93.1		%)108		(94.1		%)113	
No	%)		%)		%)		(85.7		%)		(86.3	
							%)				%)	
Belief that vaccine is not effective	0 (0.0	–	0 (0.0	–	0 (0.0	–	0 (0.0	–	0 (0.0	–	0 (0.0	–
	%)147	–	%)232	–	%)72	–	%)126	–	%)187	–	%)131	–
Yes	(100.0		(100.0		(100.0		(100.0		(100.0		(100.0	
No	%)		%)		%)		%)		%)		%)	
Belief that vaccine is not reimbursed	0 (0.0	–	0 (0.0	–	0 (0.0	–	0 (0.0	–	0 (0.0	–	0 (0.0	–
	%)147	–	%)232	–	%)72	–	%)126	–	%)187	–	%)131	–
Yes	(100.0		(100.0		(100.0		(100.0		(100.0		(100.0	
No	%)		%)		%)		%)		%)		%)	
Lack of vaccine proposal/ reminder	147	–	232	–	72	–	126	–	187	–	131	–
	(100.0	–	(100.0	–	(100.0	–	(100.0	–	(100.0	–	(100.0	–
Yes	%)0		%)0		%)0		%)0		%)0		%)0	
No	(0.0 %)		(0.0 %)		(0.0 %)		(0.0 %)		(0.0 %)		(0.0 %)	

Reasons reported by participants using a self-administered multiple-choice questionnaire for each vaccine before medical consultation. The results are only presented for patients convinced not to have been vaccinated before the study.
Abbreviations: DTP = diphtheria/tetanus/poliomyelitis; MMR = measles/mumps/rubella.

against hepatitis B (compared to 77 % in the COVAVIH study). This study also reported a rate of hepatitis A immunization of 6.8 %. It would be difficult to compare it to the COVAVIH study, where 63 % of participants did not need any hepatitis A vaccine update, because this group also included patients for whom the vaccination was not indicated according to the national guidelines (without any additional risk factor), and those who have been previously immunized through hepatitis A virus infection. Indeed, the higher immunization rate observed in the COVAVIH study does not mean a higher vaccination rate. Most COVAVIH study participants (54.7 %) were born abroad, and among them, three out of five were born in sub-Saharan Africa, where hepatitis B and A are endemic.

4.2. Reasons of low vaccination related to healthcare system

The reasons for low vaccination coverage in the COVAVIH study could be summarized as resulting from caregivers' failure to remind patients to get vaccinated, patients' misinformation and limited data about previous vaccine uptake.

PLWH are regularly followed in hospital, suggesting that the under-vaccination may be linked to many missed opportunities to remind PLWH of the need to be vaccinated. A study conducted in the general population of eastern France in 2007 [34] concluded that non-vaccination against seasonal influenza, hepatitis B and A, and *Pneumococcus* sp. was mainly related to lack of vaccine prescription by caregivers. More recent studies have shown that non-vaccination due to the lack of a reminder by a caregiver would concern 57 % [21] of unvaccinated individuals, and this proportion could reach 95 % for certain vaccines [20]. Family doctors could play a major role in patients' decision to get vaccinated or not [35–39]. They are perceived by patients as a reliable source of information about vaccines [40–42]. Indeed, in the COVAVIH study, participants who were not registered with a GP were less likely to be vaccinated against DTP and seasonal influenza than those who were. Could more frequent consultations for people with complex health conditions facilitate vaccination? In our study, the vaccine uptake did not depend on the number of consultations over the last 2 years. Moreover, vaccination rates were not associated with older age or the presence of chronic diseases. However, as expected, the rate of PLWH over 60 vaccinated against seasonal influenza was almost twice that of younger participants (see Table 3).

The low vaccine uptake could also be explained by a lack of knowledge and negative opinions about vaccination among patients, fear of side effects, doubts about vaccine efficacy and the conviction of not belonging to a high-risk group [43]. Consistently, we found in the COVAVIH study that the main reasons for vaccine reluctance were fear of injections, belief of having a contraindication to vaccines, or that vaccines are unnecessary and even harmful. This contrasted with the high willingness (70 %) to get vaccinated with at least one of the recommended vaccines. After our intervention, almost one in two participants declared their intention to receive pneumococcal vaccines,

Table 3
Factors independently associated with non-vaccination.

Background characteristics	Sample sizen (%)	dTP 191 (56.5 %)	MMR 145 (42.9 %)	Hepatitis B 245 (77.3 %)	Hepatitis A 212 (62.7 %)	Seasonal Influenza 151 (44.7 %)	Pneumococcal vaccines 207 (61.2 %)
Age group	%)79	1.1 (0.84–1.44)	0.67	0.93 (0.8–1.08)	092 (0.7–1.21)	[a]	1.06 (0.86–1.3)
<60 years	(22.5 %)		(0.43–1.04)			1	
≥60 years						**1.42 (1.04–1.95)**	
Gender	%)218	1.1 (0.87–1.4)	1.14	0.97 (0.83–1.14)	p = 0.93	1.1 (0.8–1.51)	1.03 (0.86–1.24)
Female	(64.5 %)		(0.81–1.6)		10.92		
Men and transgender					(07–1.21)		
Geographical origin	%)114	1.04 (0.79–1.37)	Not included	Not included	Not included	1.15 (0.82–1.63)	Not included
Metropolitan France	(33.7 %)27	1.24				1.31	
Sub-Saharan Africa	(8.0 %)44	(0.9–1.7)1.45				(0.88–1.93)1.07	
North Africa and Middle East	(13.0 %)	(1.12–1.86)				(0.75–1.53)	
Other							
Education	%)20	[a]	Not included	Not included	Not included	[a]	Not included
Never went to school	(5.9 %)126	1				1	
Primary school	(37.3 %)137	**3.04 (1.51–6.14)**				**3.59 (1.34–9.57)**	
Secondary school	(40.5 %)	**3.11 (1.65–5.84)**				**3.48 (1.41–8.61)**	
Higher education		**2.89 (1.53–5.46)**				**3.8 (1.53–9.41)**	
Work	%)52	0.98 (0.71–1.35)	Not included	Not included	0.82 (059–1.14)	1.17 (0.81–1.68)	Not included
Employed	(15.4 %)100	0.82			1.07	0.7	
Unemployed	(29.6 %)	(0.6–1.12)			(0.87–1.31)	(0.46–1.08)	
Other							
Type of income	%)32	1.23 (0.88–1.72)		1.04 (0.84–1.29)	Not included	[a]	Not included
Salary	(9.5 %)68	0.72		0.9		1	
Social community benefits	(20.1 %)	(0.47–1.11)		(0.75–1.08)		**1.6 (1.07–2.39)**	
Other						0.55 (0.28–1.08)	
In a relationship	%)122	0.83 (0.67–1.03)		0.91 (0.8–1.05)	0.89 (0.73–1.08)	1.02 (0.78–1.32)	Not included
Yes	(36.1 %)						
No							
Basic health insurance scheme	%)116 (34.3 %)	0.96 (0.75–1.22)	Not included	Not included	Not included	0.94 (0.68–1.29)	Not included
Yes							
No							
Vaccination records	%)149	[a]	Not included	Not included	Not included	0.83 (0.65–1.06)	0.85 (0.71–1.01)
Yes	(47.0 %)	1					
No		**0.65 (0.53–0.79)**					
HIV transmission group	%)113	1.0 (0.77–1.29)		1.10 (0.94–1.29)	[a]	1.27 (0.91–1.76)	Not included
Heterosexual	(33.4 %)55	0.97		1.04	1	1.31	
MSM	(16.3 %)	(0.73–1.29)		(0.86–1.25)	**1.3 (1.04–1.63)**	(0.91–1.89)	
Other					0.96 (0.74–1.25)		
HIV CDC stage	%)249	1.0 (0.8–1.24)	Not included	Not included	Not included	Not included	Not included
C	(73.7 %)						
Other than C							
Last CD4 cells count/mm^3	%)240	Not included	Not included	Not included	Not included	0.84 (0.66–1.08)	Not included
<500	(71.0 %)						
≥500							
Registered with a GB	%)151	[a]	Not included	Not included	Not included	0.84 (0.65–1.09)	Not included
Yes	(44.7 %)	1					
No		**0.76 (0.62–0.93)**					

Determinants of uncomplete vaccination schedule adjusted for clinically relevant covariates, including age and gender. Statistically significant results are shown in light grey.

Abbreviations: CDC = centers for disease control and prevention; DTP = diphtheria/tetanus/poliomyelitis; GP = general practitioner; HIV = human immunodeficiency virus; MMR = measles/mumps/rubella; MSM = men who have sex with men

[a] Associated with vaccination coverage ($p < 0.05$).

showing that providing information on vaccination could help to increase vaccine uptake. Factors influencing trust in vaccines include reliance on the healthcare systems, providers and government, as well as perception of the importance, safety, and efficacy of vaccines [44,45]. Understanding patients' concerns and general attitude towards vaccines is important to increase vaccine confidence [46]. It should be underlined, that scientific evidence-based communication about the benefits of vaccination and tackling misinformation help to overcome barriers and improve vaccination uptake [46]. Personal beliefs are dynamic and modifying them can affect behavior, which should be borne in mind in future educational interventions. Although trust in vaccines remains low across Europe compared to other continents, there are signs of its increase in most European countries, including in France [44].

In addition, the fact of not having vaccination record, associated in our study with the absence of vaccination against DTP, seasonal influenza and *Pneumococcus* sp. (see Table 3), could delay the decision to get vaccinated. The transition of paper documents by universal digital records should be encouraged to improve the vaccination process.

4.3. Reasons of low vaccination related to patients' features

Among patients' features found to be linked to non-vaccination there were noted, gender, patients' education level, patients' socio-economic status and their geographical origin.

Although men are more likely to receive vaccines [47–50], we found that the male gender, regardless of the geographical origin, was

associated with lower DTP and seasonal influenza vaccination coverage. This could be explained by the close monitoring of pregnant women living with HIV and routine vaccination against pertussis and seasonal influenza during pregnancy, or by the fact that men are often professionally more active family members, so that they may postpone vaccination due to work-related issues.

A recent study, highlighting trends in vaccination coverage, has shown that a lower education level, and therefore, poorer knowledge and perception of risks, were strongly associated with a lower vaccine uptake [44]. Similar association was observed in our study, for DTP and seasonal influenza vaccine uptake.

Furthermore, studies have shown that people with low socio-economic status are less likely to use preventive care, even in high-income countries like France, where the national health service is universal and there should be no financial barriers to care [51]. As hypothesized, we found that low income was associated with non-vaccination.

4.4. Strategies to develop

Strategies aiming to increase vaccination coverage require a multi-faceted approach, and should target four axes: education of patients and caregivers, rethinking the organization of preventive health checks, ensuring open and flexible access to vaccines and paying a particular attention to socially vulnerable populations.

We are convinced, that the interventions promoting vaccination must address both, patients and caregivers. One such strategic effort is training of healthcare professionals to improve their knowledge on vaccination and communication skills. Caregivers' perception of the utility of vaccines and knowledge how to adapt the message to their patients may provide an important tool to respond adequately to patients' needs to be informed. Vaccine uptake is linked to confidence in the need for getting vaccinated, and as a consequence, the acceptance of multiple doses and booster vaccines is higher in patients reporting medical conditions [45]. Indeed, feeling vulnerable and following recommendations of a healthcare professional could improve vaccine uptake in 90 % of PLWH [43]. Immunocompromised patients are 13–14 times more likely to get vaccinated against seasonal influenza, and up to 245 times more likely to receive pneumococcal vaccines if vaccine is recommended by a GP or a specialist [43,52]. This is why we assumed that our intervention could help increase vaccine uptake among PLWH.

Unfortunately, vaccination is difficult to integrate into the treatment process. It is often discussed at the end of a consultation, if there is enough time left, confirming that frequent visits to the GP do not necessarily increase the vaccination rate. The findings of COVAVIH study emphasize the importance of consultations dedicated to analyzing patients' vaccination status. A single visit focusing on vaccination may improve vaccine adherence. Furthermore, to reduce missed opportunity for vaccination, pneumococcal and influenza vaccination during hospitalization in this high risk group patients could be also a solution [53].

Easier and more flexible access to vaccines through outpatient consultations should be encouraged [54,55]. Since August 2023, pharmacists in France can assess, prescribe and administer the majority of vaccines recommended to the general population over 10 years old, including PLWH. Pharmacies offer accessibility, broad opening hours, lack of long queues and few requirements for appointments. Thus, a strategy based on pharmacist-driven vaccination may create a new, more effective model of preventive service.

Special attention should be paid to vulnerable populations, especially to migrants who combine lower education and socio-economic status, and often are not registered with GP (in COVAVIH $p = 0.001$). They have a variety of different physical and mental needs, shaped by experiences in their countries of origin, integration in the new country, as well as living and working conditions. Non-native population, low paid and less educated, supposedly, has worse chances to use preventive health system [51]. They would be particularly likely to be unvaccinated against DTP [14]. It should be noted that in the United States, 84 % of adult migrants over 50 are not protected against tetanus, while only 21 % of people born in the United States are not vaccinated [56]. This huge vaccination gap is also seen among US PLWH Alagappan et al., 2008;1 [57]):123–6.. In our study, DTP and seasonal influenza vaccination rates were lower among PLWH born in sub-Saharan Africa than among those born elsewhere. In contrast, the MSM population, mostly born in Europe (in COVAVIH $p < 0.001$), and having higher education and better socio-economic status, had higher vaccination coverage against DTP and seasonal influenza. Strategies to reduce disparities in access to preventive care, depending on socioeconomic status should be developed. Surprisingly, the French government did exactly the contrary in November 2023, approving the law which excludes people in illegal situation from access to the public healthcare system. Hopefully, it shall not impact directly PLWH already followed in France, yet, it may have deleterious effects on infectious diseases spread, like it was described in Spain after restriction to healthcare access for migrants in 2012 [58], which increased health inequities.

5. Study limitations

The study presented here has some limitations. We interviewed only French-speaking patients, thereby excluding some foreigners, which belong to particularly vulnerable population. This might underestimate the difference between patients born in France and in foreign countries.

Informal discussions through face-to-face or written communications, used in our study, seem to be effective in "Baby Boom" generation patients (born between 1946 and 1965) [59]. These strategies are less appropriate for patients belonging to generations X, Y, Z, which may be best reached through technology [59]. Communication channels tailored to reach people of different generations and thus ensure the effective delivery of information must be developed.

The COVID-19 pandemic probably affected patients' opinions and vaccination coverage, especially against seasonal influenza and pneumococcal infections [60].

Last but not least, the inclusion of variables with high p-values could have introduced some risks, such as inflation of the type I error or a reduction in the statistical power of the model.

6. Conclusion

In the COVAVIH study, the overall vaccination coverage was low, regardless of vaccine type. Strikingly, vaccine hesitancy was not a major problem, and the patients were mostly willing to get vaccinated. This discrepancy might be explained by a deficiency of provided information to patients and caregivers. Highlighting the need for greater attention to vaccination status could address the problem of missing vaccination proposals and reminders.

We are convinced that developing strategies focused on the four axes described in our work, is a key factor to increase the vaccine uptake. Large campaigns and easier access to vaccines may improve vaccination adherence. Nevertheless, it is crucial to find time to discuss patients' doubts and needs. Repeated interventions of vaccination promotion and visits dedicated to vaccination might be a solution. Special attention to socially vulnerable populations, particularly to migrants, should be encouraged.

CRediT authorship contribution statement

Agnieszka Kolakowska: Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Esaïe Marshall:** Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Evguenia Krastinova:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Agnès Cros:** Supervision, Project administration, Data curation. **Claudine Duvivier:** Writing – review & editing,

Investigation. **Pierre Leroy:** Writing – review & editing, Investigation. **Fabienne Caby:** Writing – review & editing, Investigation. **David Zucman:** Writing – review & editing, Investigation. **Arthur Maka:** Writing – review & editing, Validation, Formal analysis. **Dominique Salmon:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Antoine Chéret:** Writing – review & editing, Validation, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Claudine Duvivier: consultancies, speaker honoraria, and travel grants (Gilead Sciences, MSD, and ViiV Healthcare), outside the submitted work; Antoine Cheret: Grants for study of MSD, ViiV and Janssen Cilag. Travel grant of ViiV and Gilead; other authors declare no conflict of interest

Data availability

Data will be made available on request.

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