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Frequency of Human Immunodeficiency Virus, Hepatitis B/C Viruses, And *Treponema pallidum* Infections Among Blood Donors in Republic of Congo: A Ten Years Retrospective Study

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Abstract

Blood-borne agents such as human immunodeficiency virus (HIV), hepatitis B virus (HBV), hepatitis C virus (HCV) and *Treponema pallidum* (TP) poses a great threat to blood transfusion safety. This study investigated the frequency of these serologic markers for transfusion transmissible infections (TTI) among Congolese blood donors. This was a retrospective study which was carried out to all blood donors who donated blood at National Blood Transfusion Center, between January 2005 and December 2015. Data were statistically analyzed using the Statistical Package for Social Sciences (SPSS) software version 21.0. At all times, a p-value < 0.05 was considered as statistically significant. Of the 480365 donors, 400377 (83.3%) were males and 79988 (16.7%) females. Regarding types of donors, 73378 (15.3%) were regular, 95962 (19.9%) first-time and 311025 (64.7%) replacement donors. However, HCV and *T. pallidum* were tested only on 418268 and 397279 donations, respectively. The overall reactivity frequencies of specific antibodies to HBV, HIV, HCV and *T. pallidum* were respectively 35547 (7.4%), 13450 (2.8%), 8789 (2.1%) and 1359 (0.3%). The cumulative reactivity rate was 12.6%. In addition, the cumulative overall frequency of co-infection observed in donor population was 0.47% with HIV-HBV (0.2%) as the most important co-infection. Thus, of the 2055 co-infections observed over the period studied, 943 (45.9%) were HIV-HBV, 660 (32.1%) HBV-HCV and 288 (14%) HIV-HCV, the most common co-infections found among blood donors. In addition, the highest frequencies of TTI were observed in male donors and in the age group 31- 45 years. Also, significantly elevated frequencies for HBV, HIV and HCV were observed among replacement donors (p<0.001). Although high, a very slow decrease in these markers was noted from 2005 to 2015. This study highlighted the high frequency of TTI and a predominance among replacement donors, at-risk donors. Thus, improvements are needed to strengthen safety of blood products in Republic of Congo.

Keywords: Blood transfusion; Transfusion transmissible infections; frequency; Human immunodeficiency virus; Hepatitis B virus; Hepatitis C virus; *Treponema pallidum*; Republic of Congo

Introduction

Blood transfusion has the potential to save lives. However, it is also associated with well-defined risks that could be immunological and / or infectious. When, it is infectious, this risk is due to the transmission of viruses, bacteria and parasites [1, 2]. Thus, Blood-borne agents such as the hepatitis B virus (HBV), hepatitis C virus (HCV), human immunodeficiency virus (HIV) and *Treponema pallidum* (TP) are of great concern because of their carrier or latent state [2, 3]. They also cause fatal, chronic and life-threatening disorders [4, 5]. Transmission of these infectious agents can involve various routes, including vertical transmission, sexual intercourse, exposure to blood, and/or transfusion of unsafe blood products [6, 7]. World Health Organization (WHO) estimated that about 350, and 170 million people worldwide are chronically infected with HBV and HCV, respectively [4]. In addition, around six million individuals are infected with *T. pallidum* and 38 million individuals are living with HIV/acquired immunodeficiency syndrome (AIDS) [8, 9].

In HIV-infected persons, it is estimated that 2–4 million have chronic HBV co-infection and 4– 5 million have HCV co-infection [10]. In the context of blood transfusion, the high prevalence of HIV, hepatitis B and hepatitis C in sub-Saharan Africa area has made crucial the focus on infectious transfusion safety in this region [11, 12]. Indeed, for years it has been reported that blood transfusion was responsible for 5-10% of HIV infections and at the same time, 12.5% of patients who receive blood transfusion are also at risk of post-transfusion hepatitis in sub-Saharan Africa area [6, 13]. A review of this claim reduced the rate of HIV transmission through blood transfusion to 0.2% [14]. Nevertheless, blood safety remained a serious concern in subsaharan Africa.

To improve blood infectious transfusion safety, WHO recommends an integrated strategy including priority to voluntary blood donors, screening of donated blood for at least the four major transfusion transmitted infections (TTI) and use of quality assured assays [15].

In the last years, several previous studies have estimated the epidemiological burden of HBV, HCV and HIV infections ranking Republic of Congo as a country with high endemicity: the frequency of chronic carriage of HBV infection was 6.5 to 15% and 13.9% for HCV among poly-transfused patients [16-19]. Also, HIV prevalence survey in the Congolese general population showed the HIV rate at around 3.2% [20]. It should be added that studies carried out almost 20 years ago in hospitalized patients, blood donors and pregnant women had shown very high frequencies, especially for *Treponema pallidum* [21], but which have never been confirmed by more recent studies. In addition, the evolution over-time of the frequency of these four infectious markers had never been investigated. It is therefore not known whether the values given by these previous studies are still valid in this new context. Also, little is known about co-infections rates, except in the particular study about women who delivered at A. Cisé Hospital in 2010. Study showed co-infection rate values of 1% and 0.7% for HIV-HBV and HIV-HCV, respectively [22].

Thus, in the present retrospective study, we evaluated, over a large period of time, from 2005 through 2015, the frequency of infections and co-infections of HIV, HCV, HBV, and *Treponema pallidum* among blood donors in Republic of Congo.

Materials and Methods

Study design and population

This was a retrospective study which was carried out on all blood donors who donated at National Blood Transfusion Center in Republic of Congo, from January 2005 to December 2015.

All blood donors fulfilled individual health history questionnaire and were briefly physically examined. They were all apparently healthy subjects, aged between 18 and 60 years, weighing 50 kg or more and without apparent illness, jaundice, sickle cell disease, or current fever. Consequently, only individuals without a history of the above-mentioned diseases or risk factors for blood transmissible diseases were allowed to donate blood. There were no financial or other incentives for blood donation. All donors were regular, first-time or replacement donors. There was not remunerated donor.

Study setting and sample collection

Blood sample were aseptically collected from each subject in dry tubes. Blood was collected in four interdepartmental centers, Brazzaville, Pointe-Noire, Owando (North Network) and Dolisie (Southern Network). The two major centers by the number of donation and transfusion activities, Brazzaville (7 blood transfusion stations) and Pointe-Noire (3 blood transfusion stations), are respectively the political and economic capitals of the country. The South West (7 small blood transfusion stations) and North (20 small blood transfusion stations) are located inside the country in low or very-low transfusion activity localities. Sera specimens were separated after centrifugation at 3000 g for the analysis. Individual blood donor serum was used for serological screening.

Screening methods

Serum sample of each blood donor was screened for HIV, HCV, HBV (AgHBs), *T. pallidum*. ELISA (Enzyme linked immunoassay) was used to detect HIV (Genscreen HIV1/2 Ag-Ac Ultra from Biorad, Marne la Coquette, France; country; Vironostika HIV Ag/Ab from Bio-Mérieux, France ; Murex HIV Ag/Ab from Abbott, France). Similarly, AgHBs was determine using (Monolisa HBV Ultra, from Biorad, France; hepanostika AgHbs, from Bio-Mérieux, France; Murex AgHBs, from Abbott, France); and HCV antibody was determine using (Monolisa HCV, Biorad, France; Hepanostika HCV, Bio-Mérieux, France ; Murex HCV, France). Also, Rapid screening tests have been used to determine HIV (Determine HIV1/2 Ab, Determine Combo HIV ½ Ag/Ab, Abbott, Alere, France), AgHBs (Determine AgHBs, Abbott, Alere, France) and HCV (SD Bioline Determine, Abbot, Fance). In addition, the Rapid Plasma Reagine (RPR) test (Bio-Rad, Marne la Coquette, France) was used to detect *T. pallidum* infection. In this study, all reagents were used following the manufacturer's instructions.

In the majority of cases, no confirmatory test has been performed for blood donation samples due to limited ressources. So Any reactive sample was systematically discarded. However, a confirmatory test (second sample and different reagent) was carried out for positive the tested donor who has sought his results.

Statistical analysis

The data validated were analyzed using Statistical Package for Social Science (SPSS) for Windows version 21.0 (SPSS Inc., Chicago, IL, USA). Frequency was expressed in percentage and reported with 95% confidence intervals (95% CI) for the entire study. Differences in frequencies of TTI according to socio-demographic variables were checked for significance by binary logistic regression. Statistical significance was defined as a P-value less than 0.05 ($P< 0.05$).

Ethical statement

The study was approved by the Ethics Committee on research in the health sciences in Republic of Congo. Authorizations were obtained to confidentially used collected data in technical reports of National center of blood transfusion. The study doing a retrospective review of blood donors' records, as secondary data, informed consent was not sought from study donors.

Limitation of the study

In the context of a country with limited resources, this study was a retrospective study to find out the frequencies of the viral and bacteriological markers of the four transfusion-transmissible infections. We could not control the results or know the factors that could influence them. We had taken all the results that were reactive in the first instance, with the tests used (Elisa or Rapid Screening Tests). Any sample reactive to used tests was discarded for transfusion. It is therefore quite possible that in this context of non-prior confirmation of outcome, data have been overestimated (false positivity) or underestimated (false negativity). A study should evaluate the percentage of the biases of the data.

Results

Demographic characteristics of the blood donors

As shown in Table 1, an overall of 480365 blood donors were selected. Of these, 83.3% were males and 16.7% were females. The most common age group of donors was found to be 18-30 years (47.7%) followed by age group of 31-45 years (39.9%). Most of donors were replacement donors 64.7%, while voluntary first-time donors represented 19.9% and regular donors 15.3%.

Table 1: Socio-demographic characteristics of blood donors.

Characteristics	Number (%)	
Gender		
Male	400377	(83.3)
Female	79988	(16.7)
Age groupe (years)		
18-30	229274	(47.7)
31-45	188982	(39.9)
46-60	62109	(12.9)
Types of donor		
Regular	73378	(15.3)
First-time	95962	(19.9)
Replacement	311025	(64.7)
Transfusion Center		
Brazzaville	211262	(43.9)
Pointe Noire	177699	(36.9)
Southwest network	53518	(11.1)
North network	37886	(7.9)

Also, blood units were collected to the National Blood Transfusion Center, respectively at Brazzaville (43.9%), Pointe-Noire (36.9%), Southwest network (11.1%) and North network (7.9%).

Trends of HIV, HBV, HCV and *Treponema pallidum* infections

On 480365 blood units collected, all were screened for HIV and HBV, 418268 for HCV and 397279 for *T. pallidum*. A

total of 59145 of blood units screened were sero-reactive for one of the TTIs investigated (Table 2). Of these sero-reactive units, there were 35547 (60,10%), 13450 (22,74%), 8789 (14,86%) and 1359 (2,30%) sero-reactive blood units for HBV, HIV, HCV and *T. pallidum* respectively. In addition, of the all blood units tested the global frequency for each marker was respectively 7.4% (HBV), 2.80% (HIV), 2.1% (HCV) and 0.3% (T.pallidum).

Table 2: Frequency of HIV, HBV, HCV and *T. pallidum* infections among blood donors.

Infections	Number	Frequency in infected population (n=59145)	Frequency in blood donor population
HIV	13450	22.74%	2.80%
HBV	35547	60.10%	7.40%
HCV	8789	14.86%	2.10%
T. pallidum	1359	2.30%	0.34%

480365 as population for HIV and HBV frequency infection calculation in overall blood donor population; 418268 for HCV and 397279 for TP calculation

Figure.1 shown the frequencies evolution trend of TTIs during the studied period. The highest and the lowest frequencies were respectively, 8.4% (2005) and 6.3% (2013) for HBV, 3,5% (2005) and 2,21% (2013) for HIV, and 3,1% (2005) and 1,5% (2014) for HCV. These data shown a small but regular decrease in frequencies (Figure 1) even if these decreases were not statistically significant (data not shown). As indicated above, the number of blood donation screened for HIV, HBV, HCV and TP were different. Nevertheless, percentages of TTIs per year were added together to estimated approximatively the overall percentage of TTIs per year. The high overall frequencies of TTI were reported in 2005 (15.4 %), followed by 2007 (13.9%), while the low was reported on 2014 (12.8%). The differences between the values of frequencies of the different evaluated serologic markers (HIV, HBV, HCV, T.pallidum) at a given year were almost the same during the study period. 4.68%, 0.67% and 1.41%, average value of difference from frequencies respectively between HBV and HIV, HIV and HCV and, finally HCV and *T. pallidum*. The frequency of *T. pallidum* had remained low throughout the study period. Nevertheless, there was no statistically significant change in frequency during years of the study (P value > 0.05).

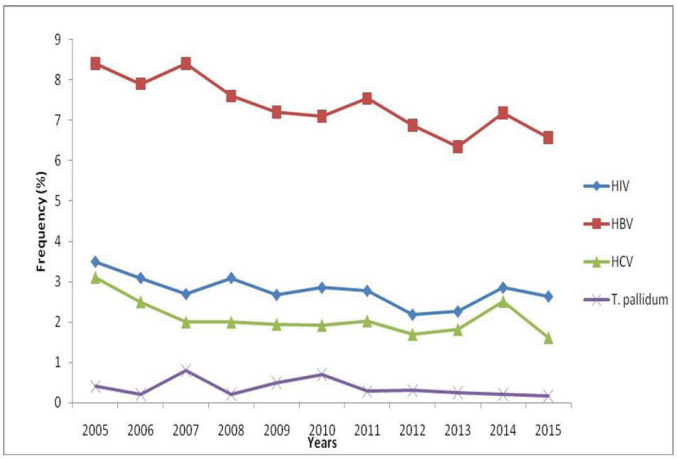

Figure 1: Trends of HIV, HBV, HCV and *Treponema pallidum* frequency among blood donors

Frequency of co-infections

The co-infection rates, in donor population of the study and the percentage of each combination of co-infection in the infected donor population are presented in Table 3. The cumulative overall rate of co-infections in donor population was 0,47% and the highest co-infection rate was observed between HIV-HBV and was 0.2%. Also, among the co-infections, 45.9% were HIV-HBV, 32.1% HBV-HCV and 14% HIV-HCV.

Table 3: Frequency of HIV, HBV, HCV and *T. pallidum* co-infections among blood donors

Co-infections	Number	Frequency in co-infected population (n=2055)	Frequency in blood donor population
HIV-HBV	943	45.9%	0.2%
HBV-HCV	660	32.1%	0.16%
HIV-HCV	288	14%	0.07%
HIV-*T. pallidum*	75	3.6%	0.02%
HBV-*T. pallidum*	55	2.7%	0.014%
HCV-*T. pallidum*	34	1.7%	0.009%

480365 as population for HIV-HBV co-infection calculation; 418268 as common denominator for HBV-HCV, HIV-HCV co-infection and 397279 for HIV-TP, HBV-TP and HCV-TP co-infection calculation

Frequency and demographic characteristics of TTIs

The overall frequency found for HBV (Table 4) was 35547 (7.4%) (95%CI: 7.2- 7.5%), for HIV (Table 5) 13450 (2.8%) (95%CI:2.65-2.94%), for HCV (Table 6) 8789 (2.1%) (95%CI: 1.95 –2.25%), and 1359 (0.3%) (95%CI:0.19-0.51%) for *T. pallidum* (Table 7). Highest frequencies rates of HIV, HCV and *T. pallidum* were found in the age group 31- 45 years followed by those over 45 years (Table 5, 6, 7), while HBV was high in age group 18-30 years (Table 4). A statistically significant difference was observed on the carriage of HIV and HBV infections with all age groups of donors. However, for HCV and *T. pallidum* infections, a statistically significant relationship was observed only for those which have more than 30 years of age (p<0.05).

All types of TTIs were found among male and female donors. Higher frequency in men than in women was observed for HBV, HCV and *T. pallidum*. Differences were statistically significant for HBV and *T. pallidum* (Table 5, 6, 7) infections. Only HCV (P = 0.115) shown no statistically significant difference between male and female donors (Table 6). Indeed, for HIV, the frequency of women was significantly higher than that of men (Table 6)

The frequency of HIV, HBV and HCV were significantly increased among replacement donors compared to voluntary donors (p = 0.001). A higher reactivity in replacement donors was also noted for *T. pallidum*, although the difference was not statistically significant for first-time donors (OR, 1.07: 0.86-1.34; *p* = 0.528) (Table 4, 5, 6, 7).

Table 4: Frequency of HBV by gender, age and type of donor type

Variables	HBV reactivity			COR (95% CI)	P-Value
	Reactive (*)	Non-reactive	Total		
Gender					
Male	32178 (8)	368199	400377	1.99 (1.92 – 2.06)	0.001
Female	3369 (4.2)	76619	79988	1	
Age group					
18-30	19774 (8.6)	209500	229274	2.37 (2.27 – 2.48)	0.001
31-45	13390 (7.1)	175592	188982	1.91 (1.83 – 2)	0.001
46-60	2383 (3.8)	59726	62109	1	
Donor type					
Regular	926 (1.3)	72452	73378	1	
First-time	5798 (6)	90164	95962	5.03 (4.69 – 5.39)	0.001
Replacement	28823 (9.3)	282202	311025	7.99 (7.48 - 8.53)	0.001

COR= Crude Odds Ratio ; CI= Confidence interval ; (*) : sero-reactivity percentage in the group. 480365 as overall number of donation

Table 5: Frequency of HIV by gender, age and type of donor

Variables	HIV reactivity			COR (95% CI)	P-Value
	Reactive (*)	Non-reactive	Total		
Gender					
Female	2646 (3.3)	77342	79988	1.23 (1.18 – 1.28)	0.001
Male	10804 (2.7)	389573	400377	1	
Age group					
18-30	5371 (2.3)	223903	229274	1	
31-45	6436 (3.3)	182546	188982	1.3 (1.23 – 1.37)	0.001
46-60	1643 (2.6)	60466	62109	1.13 (1.07 1.2)	0.001
Donor type					
Regular	517 (0.7)	72861	73378	1	
First-time	2130 (2.2)	93832	95962	3.2 (2.91 – 3.52)	0.001
Replacement	10803 (3.5)	300222	311025	5.07 (4.64- 5.54)	0.001

COR= Crude Odds Ratio ; CI= Confidence interval ; (*) : sero-reactivity percentage in the group 480365 as overall number of donation

Table 6: Frequency of HCV by gender, age and type of donor type

Variables	HCV reactivity			COR (95% CI)	P-Value
	Reactive (*)	Non-reactive	Total		
Gender					
Male	7380 (2.1)	342243	349623	1.03 (0.97 – 1.09)	0.115
Female	1409 (2)	67236	68645	1	
Age group					
18-30	3952 (1.9)	197758	201710	0.99 (0.93 – 1.05)	0.995
31-45	3490 (2.3)	145260	148750	1.19 (1.12 – 1.27)	0.001
46-60	1347 (1.9)	66461	67808	1	
Donor type					
Regular	330 (0.4)	62170	82500	1	
First-time	1307 (1.8)	71304	72611	3.45(3.06 – 3.89)	0.001
Replacement	7152 (2.7)	256005	263157	5.26 (4.71- 5.88)	0.001

COR= Crude Odds Ratio ; CI= Confidence interval. (*) : sero-reactivity percentage in the group; 418268 as overall number of donation

Table 7: Frequency of *T. pallidum* by gender, age and type of donor type

Variables	*T. pallidum* reactivity			COR (95% CI)	P-Value
	Reactive (*)	Non-reactive	Total		
Gender					
Male	1168 (0.4)	295721	296889	2.8 (1.78 – 2.42)	0.001
Female	191 (0.2)	100199	100390	1	
Age group					
18-30	541 (0.3)	178799	179340	0.98 (0.83 – 1.15)	0.658
31-45	621 (0.4)	153636	154257	1.3 (1.11 – 1.53)	0.001
46-60	197 (0.3)	63485	63682	1	
Donor type					
Regular	113 (0.2)	50267	50380	1	
First-time	264 (0.2)	119495	119759	0.98 (0.79 – 1.22)	0.528
Replacement	982 (2.4)	226158	227140	1.93 (1.59 - 2.35)	0.001

COR= Crude Odds Ratio ; CI= Confidence interval. (*) : sero-reactivity percentage in the group; 397279 as overall number of donation.

Discussion

In this study, the total annual number of blood donations tested had increased steadily with a cumulative total of 480365 from 2005 to 2015. The annually median rate of donors was 48037. Thus, as congolese population is around 5 million, blood donors rate was 9 per 1000 of the population, what is insufficient to meet transfusion demand. The majority of donors (83.3%) were males, results similar to the studies done in Nigeria and Libya with 98% and 99.6%, respectively [23,24]. This male dominance may be explained by the fact that among women, obstetrical factors including pregnancy, breastfeeding and menstrual cycle further restrict them from donating blood [25].

However, this low percentage of women donors can be also explained by the lack of donation culture especially in low-income countries like those in Africa. Women are rarely associated, involved in blood donation awareness campaign. It is well known that women and children are the major consumers of transfusion, especially in these low-income countries. Women who give life could also greatly help to save it by donating blood. In some developed countries, like France, there are more women (52%) than men (48%) who donated blood in 2016 [26]. In addition, a great deal of sensitization work needs to be done around quality blood donation throughout society, since the very high percentage of replacement donors (64.7%), compared to voluntary donors (15.3%), is very far from the WHO recommendations (80 - 100% voluntary donations) [15].

Hepatitis B and C are among the most infectious diseases and are also hyper endemic in sub-Saharan Africa and Asia [4]. In our study the frequency rate of HBsAg (HBV) was 7.4%. This frequency is lower than 10.9% in Nigeria, 12.7 in Senegal and 16.5% in Mauritania [11, 23]. However, our current finding is higher than 4.7 % in Ethiopia [27] and 0.9% % in China [28] among blood donors. From our study, the frequency rate of HCV was 2.1%, this is low when compared with 3.5% in Egypt and 13.3% in Ethiopia [29, 30]. Our finding is higher than values reported from Cameroon 1.65% [31] and 0.5% in China [28]. These HBV and HCV frequencies are within the average values found in others countries, and they decrease during the study period. This epidemiological trend to the slow and regular decline in HBV and HCV frequency may be due to self-selection of blood donors and the selection of donors who are at a lower risk for infection.

The frequency of HIV in our study, 2.8% which is lower when compared with an overall blood donors frequency of 7.8% in Equatorial Guinea [32] and 8.7% in Tanzania [33] but higher than study from Burkina Faso with 1.8% and 0.1% in China [28, 34]. The subsequent slow decline trends of HIV infection observed over the study period may be due to the effect of the prevention programs that have been instituted in recent years. This observed decrease of HIV infection in donor population will also improve blood safety. Nevertheless, improved strategies should continue to decrease HIV infection among blood donors.

In our study, 0.3% of donors were reactive for *T. pallidum*. After some increase or decrease variations between 2005 and 2011, a small but continuous decrease is noted from 2011 to 2015. This finding, in accordance with those of other African studies, indicates a decreasing trend in the frequency of *T. pallidum* among blood donors. The decreasing trend was observed in Cameroon [35], Tanzania [33] and Ghana [36]. Globally, *T. pallidum* infection had decreased in the world for years but in countries like China it increased [28, 37]. The used reagent was RPR. RPR rate was low in our study. Nevertheless, it was the found frequency value during ten years. Also, in Congolese pregnant women, RPR prevalence was 3.92 [38]. But, in blood donor, proportion of women was low (17%).

Consequently, the low level found in this study and the continued decrease noted, can be explained by prevention campaigns against sexually transmitted diseases, including HIV and targeted use of antibiotic therapy, also by the low number of blood women donors. We must also add the selection of donors which probably eliminates the contaminated, which contributes to lowering the frequency of markers, especially RPR compared to the overall population.

As we have just indicated in the specific cases of the four markers of this study, the decrease of the frequencies over the studied period was slow, progressive, with approximately the same amplitude. It is as if the impacts of the various elements that affect frequency do so in a comprehensive and integrated way. Actions against a given infectious marker would also act on other markers. Ultimately, this trend should facilitate the global control of these blood-borne infections.

In addition, the results on co-infections of the four TTIs markers were consistent with this analysis. The most observed co-infections are between HBV, HIV and HCV, in a hierarchical frequency. Thus, among all blood donors, the co-infection rates for HBV-HIV, HBV-HCV and HIV-HCV were 0.2%, 0.14% and 0.06% respectively. Also, among co-infected donors, the dominant co-infections were hierarchically HBV-HIV (45.9%), HBV-HCV (32.1%) and HIV-HCV (14%). Compared with studies in other countries, the dominant co-infections were not the same and did not have the same hierarchy. Thus, the most common combinations among blood donors in North-West Ethiopia were HIV-TP (38%) and HIV-HBV (34%) [27] while to hospitalized patients before transfusion at Xiangya Central Hospital in China, they were HBV-TP, HBV-HCV and HCV-TP [37]. These two studies showed the importance of *T. pallidum* in the context of these studies [27, 37] whereas in our study the frequency of *T. pallidum* was very low. This finding might be due to the fact that, not only these pathogens share common modes of transmission and risk groups [10] but also their individual frequency may be high [39] and probably associated to the environmental and socio-economic parameters of the country. However, these data are important to know, as co-infections may lead to more severe disease outcomes and faster disease progression [40]. These levels of co-infection in transfusion lead to the establishment of a rigorous selection process of blood donors. This is especially true since the frequency or prevalence rates of markers of transfusion-transmissible infections, as well as their evolution, varied in space and time [27, 28, 37, 39].

In our study, TTI frequencies were higher among male donors with statistically significant difference ($p<0.01$). This finding, was similar to those obtained in Equatorial Guinea and Tanzania [32, 41]. The high proportion of male donors can explain this fact and also, probably due to a difference in exposure to risk factors between our male and female blood donors. Indeed, studies have shown that there was no relationship with gender of donors when exposure to risk factors was the same [42-44].

Taking into account age, a significant increase in the frequency of HIV, HCV and *T. pallidum* was observed in the age group of 31-45 years compared to age groups under 30 or over 45 years of age. This was in concurrence with previous reports in China [42] and in Ethiopia where higher frequency was observed among youths [27]. This high frequency found in this population professionally active, economically important, was a serious problem. It is also the most productive and sexually active age group, which would explain this level of frequency of these sexually transmitted infections [7]. In addition, this age group was the second that provides a lot of blood donors. Consequently, It was important to implement prevention strategies for high-risk behavior changes, while bearing in mind that the high proportion of HBV observed in this study among donors aged 18 to 30 years could be also explained by the impact of mother-to-child transmission [45].

This high frequency of TTI was significantly increased among replacement donors compared to voluntary donors ($p<0.05$). This is in agreement with the previous studies [27, 39, 42]. It had been well documented that replacement donors are less Suitable for blood donation by the fact that people give blood because of urgent need, have these high-risk behaviors and thus are more prone to be infected by these pathogens [46]. On the contrary, people who voluntarily commit themselves to regularly donate blood consider their blood safe, because they do not have high-risk behaviors such as unprotected sexual inter-course [25]. One of the main recommendations of the WHO to transfusion safety was to consider blood donation from voluntary regular non-remunerated donors who have a lower risk of TTIs compared to replacement and commercial donors [15, 25].

Conclusion

The results of this study highlighted the slow, progressive, global and integrated decline of the frequencies of HBV, HIV, HCV and *T. pallidum* in blood donors over the study period. However, these TTI frequencies remained high, especially among young donors and particularly in the replacement donor category. Also, co-infections remain for their influence in disease progression to be considered. Thus, to achieve WHO'S recommendations taking in account the overall context portrayed in this study, it is necessary to interest also women in voluntary blood donation, to introduce effective strategies for the selection of blood donors and sensitive algorithms for screening blood donations to improve transfusion-infectious safety in the Republic of Congo.

Acknowledgments

The authors declare that they have no competing interests.

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AB conceived the study, participated in the design of the research and drafted the manuscript. BMA performed the statistical analysis and edited the manuscript. BB supervised serological analysis and centralized results. JPP, FD and DBM participated in the design and the collection of the data. All authors read and approved the final manuscript.

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