Title

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Journal

Vox Sanguinis, 116(2)

ISSN

0042-9007

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Publication Date

2021-02-01

DOI

10.1111/vox.13002

Peer reviewed

HHS Public Access

Author manuscript

Vox Sang. Author manuscript; available in PMC 2021 April 04.

Published in final edited form as:

Vox Sang. 2021 February ; 116(2): 207–216. doi:10.1111/vox.13002.

10-Year Analysis of Human Immunodeficiency Virus Incidence in First-time and Repeat Donors in Brazil

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Abstract

Background and objectives—Incidence in first-time and repeat blood donors is an important measure of transfusion-transmitted HIV infection (TT-HIV) risk. This study assessed HIV incidence over time at four large blood centers in Brazil.

Materials and methods—Donations were screened and confirmed using serological assays for HIV from 2007 – 2016, and additionally screened by nucleic acid testing from 2011 forward. Limiting antigen (LAg) avidity testing was conducted on HIV seroreactive samples from first-time donors to classify whether an infection was recently acquired. We calculated incidence in first-time donors using the mean duration of recent infection and in repeat donors using classical methods. Time and demographic trends were assessed using Poisson regression.

Results—Over the 10-year period, HIV incidence in first-time donors was highest in Recife (45.1/100,000 person–years (10^5 py)) followed by São Paulo (32.2/10^5 py) and then Belo Horizonte (23.3/10^5 py), and in repeat donors was highest in Recife (33.2/10^5 py), Belo Horizonte

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Conflict of interest

The authors have disclosed no conflicts of interest.

(27.5/10^5 py) and São Paulo (17.0/10^5 py). Results from Rio de Janeiro were available from 2013 to 2016 with incidence in first time donors of 35.9/10^5 py and repeat donors from 2011 to 2016 of 29.2/10^5 py. Incidence varied by other donor demographics. When incidence was considered in 2-year intervals, no significant trend was evident. Overall residual risk of TT-HIV was 5.46 and 7.41 per million units of pRBC and FFP transfused, respectively.

Conclusion—HIV incidence in both first-time and repeat donors varied by region in Brazil. Clear secular trends were not evident.

Keywords

Blood safety; donors; residual risk estimation; serological testing; transfusion- transmissible infections

Introduction

In Brazil there are more than 3.5 million voluntary blood donations per year. Donors are differentiated as to whether they are providing replacement donation (donation in order to replenish the stock of blood because of the need for blood transfusion to a family member or person who has some relationship with the donor) and community donation (voluntary donation to support the overall blood supply) [1]. In Brazilian Public Health Service blood centers most donations are from repeat donors (RD), but at the national level donations are equally distributed in first-time donors (FTD) and RD [1].

Trends in Human Immunodeficiency Virus (HIV) incidence in blood donors and the residual risk of transfusion-transmitted HIV in Brazil are unknown. Donations with incident infection, particularly the ones only detected by nucleic acid testing (NAT), have an increased chance of being missed by current screening assays and could lead to transfusion transmission. The higher the incidence in the donor population, the greater the likelihood of donations in the pre-NAT and pre-seroconversion window periods. Therefore, monitoring incidence over time provides an assessment of changes in infection risk in donors as well as an indicator of potential public health concern.

Calculating incidence in repeat donors relies on classical methods [2]. However, incidence can also be calculated in first-time donors using cross-sectional approaches that rely on measures of HIV antibody maturation. Persons with recently acquired infection have lower anti-HIV IgG antibody avidity. The HIV-1 limiting antigen avidity enzyme immunoassay (LAg-Avidity EIA) measures antibody avidity in persons who have seroconverted and allows classification of infections as ‘recent’ or ‘long-term’[3]. The objective of this study is to assess changes in HIV incidence in blood donors over time in different geographic locations and to monitor trends in HIV incidence in FTD and RD based on the demographic characteristics of the blood donor population in the different geographic locations.

Materials and methods

Study Setting

We estimated HIV incidence in four large public blood centers in Brazil. Together these centers collect approximately 10% of all donations in the country [4]. Donor and donation data from January 1, 2007 to December 31, 2016 were included for Hemominas in Belo Horizonte, Hemope in Recife, and Fundação Pró-Sangue in São Paulo. Hemominas, Hemorio and Fundação Pró-Sangue are located in the Southeast, and Hemope in the Northeast of Brazil. Complete data for Hemorio in Rio de Janeiro were available from January 1, 2013 to December 31, 2016 for first-time donors, and from January 1, 2011 to December 31, 2016 for repeat donors. This study was conducted as part of the NHLBI Recipient Epidemiology and Donor Evaluation Study (REDS)-II and -III Brazil program.

Donor and donation data during the study period were collected into a centralized database. The scope of the data captured in the REDS-II (from 2007 to 2012) and REDS-III (from 2013 to 2016) databases in Brazil has previously been described [5] [6]. Briefly, potential donors included all candidates for blood donation who answered screening questions that included the donor's health history, a brief physical examination with vital signs and a hematocrit/hemoglobin test. Donor eligibility was further assessed through a face-to-face interview with standardized questions, including HIV risk behaviors and risk factors for other transfusion-transmitted infections. RTI International, the data-coordinating center for REDS-III, performed all statistical analyses.

Laboratory Methods

Samples from all donations were screened by two HIV chemiluminescence immunoassays (ChLIA) or EIAs in parallel from 2007 to 2011 and with one serological assay and NAT in minipool format of 6 donations per pool starting on various dates in 2011 at each site to 2017. Routine donation screening tests were completed according to standard operating procedures at each center, and the specific serological assay reagents in use at each center may have varied over time based on the procurement process used in Brazil. The NAT test for HIV, HCV, and HBV is the Bio-Manguinhos NAT assay in a minipool format of 6 donations. The assay is the same for all Brazilian Public Health Service blood centers, and is used to test about 60% of the overall blood supply in the country [7]. All screening test results were reviewed individually for each donor including the results from additional testing of samples obtained by the centers at the time of donor return for confirmation testing and notification. If a final status could not be defined based on these results (e.g. EIA reactive and NAT negative or not available, with no additional routine testing results available) we performed Western blot (MP Diagnostics HIV Blot 2.2) on the donation sample at a central laboratory in Sao Paulo.

Available HIV EIA reactive samples were tested at Vitalant Research Institute (San Francisco, CA) using the LAg Avidity EIA (Sedia BioSciences, Portland, OR). In accordance with the manufacturer's instructions for use, samples with an initial normalized optical density (ODn) value of ≤2.0 were retested in triplicate, with the median of the retest

results constituting the final result. Any sample with a final ODn of ≤1.5 was classified as a recently acquired infection [8].

Calculation of incidence among first-time donors

We defined a FTD to be someone with no history of donation at the participating blood center. A FTD with an HIV-negative donation could also contribute to the RD analysis if that person donated at least one more time after their first donation. FTD with unknown or indeterminate HIV status or having long-standing infections (based on LAg) were excluded from the numerator and denominator of the incidence calculation. We used LAg results to derive incidence using a mean duration of recent infection (MDRI) of 129 days, which is the estimated MDRI for HIV clade B infection using an ODn threshold of 1.5 [9]. HIV incidence was computed as the number of recent infections over person-years. Uninfected donors contributed 129 days each to the total time at risk (denominator), while recently infected donors contributed 64.5 days, based on the assumption of HIV infection occurring, on average, at the mid-point of the MDRI. Results were reported as the HIV infection rate per 100,000 person years ($/10^5$py). These estimates were adjusted for non-LAg avidity tested HIV-positive samples assuming the same proportion of recent and long-term infections as in the tested population. Wald 95% confidence intervals (CI) were calculated for each rate.

Incidence by blood center was calculated overall and for each of the following 2-year periods: 2007–08, 2009–10, 2011–12, 2013–14 and 2015–16. We generated these estimates individually for each center and then in aggregate for all three centers. For donors from Rio de Janeiro, we calculated incidence for each of the last 2 time periods (data available starting in 2013).

Calculation of incidence among repeat donors

Repeat donors were defined as any person who made at least two donations during the 10-year study period. Because our analysis was divided into five two-year period, donors only contributed to incidence in the two-year intervals in which they had two or more donations. For example, a donor that made their first ever donation in the second interval (2009–10) would contribute to FTD person-years in the second interval. If the donor made a second donation in the same interval, then the donor would also contribute person-years to RD incidence. If the donor made two or more donations in the third interval (2011–12), after making at least one in the second interval, then that donor would further contribute person-years to RD incidence in the third interval.

Repeat donors with HIV infection are assumed to be infected at the mid-point of the inter-donation interval. The total individual inter-donation intervals for uninfected donors and half of the inter-donation intervals for infected donors are then summed to determine the total person-years. The incidence rates are calculated as the number of infections divided by the py, reported as $/10^5$ py, and with associated Wald 95% CIs.

Calculation of residual risk for first-time and repeat donors

The residual risk (RR) was estimated by multiplying the overall incidence estimate for 2015–16 with a model-based estimate of the infectious window period (‘risk day

equivalents') with minipool NAT screening using the Bio-Manguinhos NAT assay. The model relies on virus doubling time during ramp-up phase viremia [9] the probability of non-detection by minipool NAT screening – estimated using the reported 50% and 95% limits of detection (LoD), calculated from analytic standards [7], the probability of infection when a single virion is present in the transfused product (per-virion infectiousness) [10] and transfused volume of plasma. The per-virion infectiousness is inferred from limited data generated using the Simian Immunodeficiency Virus (SIV) Macaque transmission model for HIV infection [11]. We estimated a point estimate and plausible range for the residual risk of HIV transmission by packed red blood cell (pRBC) and fresh frozen plasma (FFP) transfusion, with an average of 20mL and 200mL of plasma, respectively [10] [12]. The plausible range is based on the lower and upper bounds of the incidence estimate confidence interval and a range of assumed per-virion infectivity levels. The upper end of the range was conservative since it assumed an infectious dose at which no animals in the SIV Macaque studies were infected [11].

Statistical analysis

We analyzed data using SAS 9.4 (SAS Institute, Cary, North Carolina, USA). Results are reported by FTD/RD status and blood center. Other potentially important variables influencing incidence included age and sex, type of donation (community or replacement), and calendar time interval. To assess which factors were independently associated with incident infection in multivariable analysis, we employed backward elimination using predictor variables associated with HIV infection at a level of $p \leq 0.05$ from bivariable analyses. The final multivariable models include variables significantly associated with incident HIV infection in FTD and RD at a level of $p \leq 0.05$. Confidence intervals for incidence adjusting for covariates were computed using multivariable Poisson regression. For each parameter included, the Poisson regression model estimates the confidence intervals, and the Wald chi-square statistic and associated p-value. The relative incidence (incidence rate ratio) for levels or categories of each predictor variable compared to the reference group within each variable are reported as exponentiated values to indicate excess risk in incidence in different levels of each categorical variable. Values above 1 indicate greater incidence relative to the reference group and values below 1 indicate lower incidence, adjusting for all other factors included in the model. HIV incidence rates were compared for the five 2-year calendar periods, and we used Poisson regression to assess linear trends in incidence over calendar time. The residual risk model was implemented in Python 3.7 (Python Software Foundation, Beaverton, OR, USA) and is publicly available [13].

Ethical considerations

Study protocols were approved by the Federal Committee on Human Subjects (CONEP) of the Ministry of Health in Brazil as part of the REDS-II/III International Program, local ethical committees at each blood center, and also the UCSF and RTI IRBs in US.

Results

The four blood centers together collected over 400,000 donations per year during the study period. The study population in Recife, Belo Horizonte and São Paulo comprised 930,180 (36.6%) FTD and 1,614,172 (63.4%) donations by RD (Table 1). Hemorio was not included in the 10-year analysis. We did include data from Hemorio consisting of 173,497 (73.5%) FTD between 2013 and 2016, and 62,447 (26.5%) RD between 2011 and 2016. The overall incidence of HIV among FTD was 34.4/10^5 py and among RD was 25.1/10^5 py. The HIV incidence varied by blood center, from 45.1/10^5 py in Recife to 23.3/10^5 py in Belo Horizonte among FTD and from 33.2/10^5 py in Recife to 17/10^5 py in São Paulo among RD (Table 2). There were no significant trends by 2-year intervals either overall or by individual blood center (Figure 1) for FTD or RD incidence rates.

Incidence in first-time donors (FTD)

Among FTD the HIV incidence was highest in Recife (45.1/10^5 py) followed by Sao Paulo (32.2/10^5 py) and then Belo Horizonte (23.3/10^5 py) (Table 2). Overall, Belo Horizonte had the lowest incidence in FTD donors in each 2-year period, except 2009–2010 (36.3/10^5 py). When stratified by age, the highest HIV incidence was observed among blood donors <24 years old in Recife at 53.8/10^5 py. In São Paulo and Belo Horizonte the highest incidence was among donors 25 to 34 years old (43.2/10^5 py and 29.5/10^5 py, respectively). By 2-year interval, incidence varied among FTD donors, but no specific trend was evident. The results for Rio de Janeiro show incidence rates in FTD in the 2 later 2-year periods (2013–14 and 2015–16) to be similar in magnitude to those in Recife and Sao Paulo. HIV incidence in FTD donors was highest in Recife males, community donors and those <24 years of age, all over 50/10^5 py. Incidence in FTD male donors in Sao Paulo was also over 50/10^5 py (Table 2). HIV incidence among FTD was higher among community donors compared to replacement donors in all sites. The left panel of Figure 2 shows the age-stratified incidence rates for FTD. The results do not show any specific patterns or trends for FTD.

In the multivariable analysis, two factors were significantly associated with HIV incidence in FTD. The incidence risk ratio was 0.24 (95% CI 0.14 – 0.41) times lower in females compared to males and 2.39 (95% CI 1.54 – 3.70) times higher in community donors compared to replacement donors. No other factors including blood center, age or 2-year interval were significantly associated with incidence in FTD.

Incidence in repeat donors (RD)

Overall, the incidence in RD was highest in Recife followed by Belo Horizonte and São Paulo. The results for Rio de Janeiro show incidence rates in RD in the 3 later 2-year periods to be similar in magnitude to those of the other centers. The HIV incidence was higher among younger blood donors (< 24 years old) and decreased with age at each of the three blood centers (Table 2). High variability was evident in each of the 2-year intervals when comparing age groups (Figure 2). We found higher incidence of HIV among community as compared to replacement donors in Recife (37.7/10^5 py vs. 24.8/10^5 py), Belo Horizonte (27.9 vs. 13.3/10^5 py) and São Paulo (17.5 vs. 8.1/10^5 py). The right panel of Figure 2 shows

the age-stratified incidence rates for RD with lower incidence in older RD more evident in Recife and Belo Horizonte.

Multivariable analysis showed a significant difference between the blood centers. The incidence rate ratio in RD was 1.91 (95% CI 1.25 – 2.93) times higher in Recife and was also borderline significantly higher in Belo Horizonte compared to Sao Paulo (Table 3). Similar to FTD, the incidence risk ratio in RD was 0.31 (95% CI 0.18 – 0.54) times lower in females compared to males and 1.78 (95% CI 1.16 – 2.74) times higher in community donors compared to replacement donors. In addition, incidence rate ratios ranged from 6 to 3-fold higher in age groups <24, 25–34, 35–44, respectively, compared to ≥45-year-old RD. Following multivariable adjustment, we did not observe incidence differences in RD by 2-year intervals.

Residual risk of HIV transfusion transmission

We estimated contemporary residual risk of TT-HIV, after the adoption of MP6 NAT screening for HIV. We used a weighted average of first-time and repeat donor incidence, weighted according to the numbers of donations from each group at each center for 2015–16. The overall residual risk for HIV was 5.46 (plausible range: 3.07 to 8.47) and 7.41 (4.41 to 11.03) transmissions per million pRBC and FFP transfusions, respectively (Table 4). Additionally, residual risk in a best-case scenario (better sensitivity of the NAT assay, as reported using clinical samples)[7] was estimated at 2.26 per million pRBC transfusions, and in a worst-case scenario (a single virion in the product would cause transfusion-transmitted infection) was estimated at 8.88 per million pRBC transfusions.

Discussion

In this study we found incidence is higher in FTD compared to RD donors, consistent with data reported for other countries. However, the incidence rates in FTD and RD donors in Brazil are more similar in magnitude than reported for other countries [14] Incidence in both FTD and RD varied between the blood centers, type of donation, and by donor demographic characteristics of age and sex.

Our 10-year analysis expands previous findings showing that HIV incidence was higher among community rather than replacement blood donors [6] and challenges WHO guidelines, which recommend community over replacement donation [1]. The conventional thinking is that replacement donors may feel compelled to donate and therefore may not fully answer screening questions intended to exclude donors with infectious disease risks hence leading to higher infection rates in replacement donors, but our results do not align with this expectation. The reasons why HIV incidence is higher in community donors in Brazil are not known. Previous results from our group have shown that test-seeking behavior is higher among HIV-positive blood donors than donors with no infection[15]. In our previous study, although the proportion of test seekers was higher among replacement donors, this association was not maintained in multivariable analysis [16]. Therefore, test-seeking behavior is not a simple explanation for why community donors had higher HIV incidence. Test-seeking behavior is also associated with male gender, lower educational attainment, and lower income [16]. Lack of knowledge of locations for free and confidential

public HIV testing services as well as dissatisfaction with past experiences with HIV testing have been associated with test seeking at blood centers [17]. In our current study, we do not know if any of these factors contribute to incidence rates in FTD or RD.

New strategies in donor recruitment and screening are necessary to avoid the risk of HIV and others infectious diseases transfusion transmission. A possible model for Brazil would be to continue to recruit replacement donors, but to focus effort on conversion of those donors to community donors whether they are first-time or repeat donors [1]. However, this may be difficult to achieve without effective messaging strategies since the return rate of replacement FTD is around half that of community FTD [18]. Additionally, use of pathogen reduction has been shown to be effective to reduce risk of TTI, especially when it becomes available for all blood components. Currently, only plasma and/or platelet inactivation procedures are licensed by the US FDA, European Union, and other countries [19]. At this time pathogen reduction is not being considered for adoption by Brazilian Public Health Service blood centres.

Another aspect of our findings is the age distribution of HIV incidence among blood donors. It is expected that HIV incidence would be higher among young individuals, whether FTD or RD, due to a more active sexual life in younger ages. This pattern is observed among RD but not among FTD. Another relevant point to note is that in Recife and Belo Horizonte the young RD have a higher incidence than young FTD. One reason for this could be that ‘at risk’ young individuals are donating more frequently than those at lower risk in the same age groups. Efforts to understand the motivations to donate and the possibility of test-seeking in this group may help blood centers to develop specific strategies to reduce donation from younger higher risk donors.

Estimation of residual risk is an important tool to assess whether reductions in TT-HIV risk are being achieved [20]. Previous research in the Northeast of Brazil for the period 2012–2014 from the State of Pará (with approximately eight million inhabitants) support the order of magnitude of the residual risk we report [21]. Our estimates show that residual risk of HIV transfusion transmission in Brazil is higher than in many other countries, such as Germany, reported as 0.52 [22], France 0.40 [23] and Canada 0.04 [24] per million RBC transfusions. At 5.21 per million RBC transfusions, similar residual risk results to ours have been reported for Italy [25]. In our study we estimated RR for both RBC and FFP based on the amount of plasma in each component to help further define risk to recipients in Brazil.

Our study has limitations. First, we did not have complete data for Rio de Janeiro available for the entire study period, so we were unable to assess demographic factors or trends over time for that blood center. A second limitation is that our study was conducted at four blood centers; as a result we are not able to comment on trends in HIV incidence in blood donors in other regions Brazil. Despite these limitations, we believe the results from the four centers are indicative of general trends in HIV infection in donors in Brazil. The difference in the incidence of HIV in males compared to females was stable over time, and age and regional differences that are consistent with the known epidemiology of HIV infection in Brazil were evident. A third limitation is that the proportion of first-time donors for whom we had samples we could test using LAg avidity was 72.2%, so almost three-quarters of first-time

donors with HIV infection had LAg avidity results. We believe this proportion of tested samples is sufficiently high to give us confidence our incidence calculations are accurate. We have no reason to be think that sample availability would be different between samples that tested recent versus longstanding on the LAg Avidity assay, thus we do not believe our findings are biased. However, we may have reduced precision in the form of wider confidence intervals as a result not being able to test all samples from HIV positive first-time donors.

In summary, these incidence results show that a substantial number of HIV-infected donors are presenting to donate within 4 months of HIV acquisition in Brazil. Over the 10-year study period this did not substantially change and consequently the residual risk of HIV transmission has remained higher than in developed countries even after the introduction of NAT screening. Our findings suggest that it remains important to continue efforts in donor education and refinement of donor recruitment strategies that promote the disclosure of risk at the time of donation. Reducing donation among the cohort of donors with recently acquired HIV infection is the most assured way to reduce the risk of transfusion-transmitted infection, and particular attention is needed for RD, age groups, and regions with the highest incidence of HIV.

Acknowledgements

We would like to thank George Rutherford, Sheri Lippman, Matt Price and Nancy Hills from the UCSF for their review and their thoughtful comments.

Funding

Data collection and analysis were funded by the U.S. National Institutes of Health (NIH) National Heart, Lung, and Blood Institute (NHLBI) Recipient Epidemiology and Donor Evaluation Study (REDS-III), International Component Brazil (HHSN268201100007I), by a training grant from VRI, and by UCSF from the following grants from NIH: National Institute of Mental Health (NIMH), Center for AIDS Prevention Studies (P30 MH062246), International Traineeships in AIDS Prevention Studies (ITAPS, R25MH064712).

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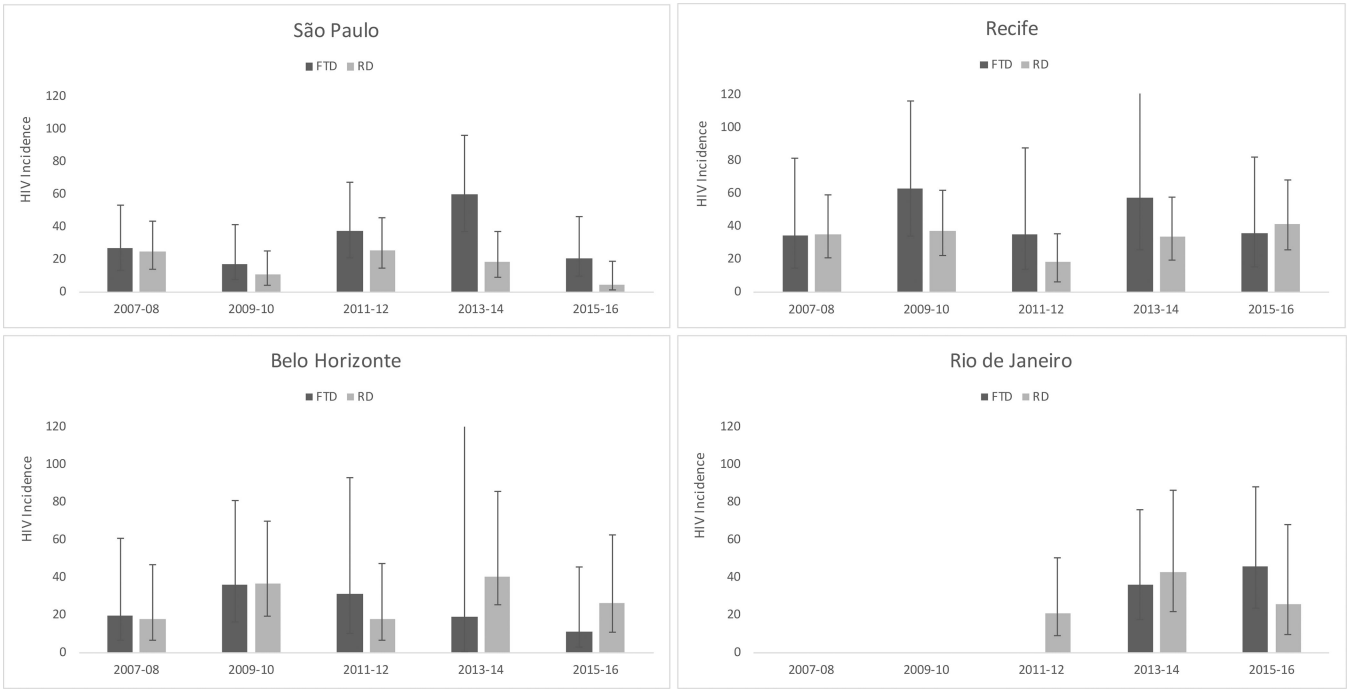

Figure 1.

HIV Incidence per 100,000 Person Years and 95% Confidence Interval by Time Interval and Blood Center for First-Time (FTD) and Repeat Donors (RD), 2007 to 2016

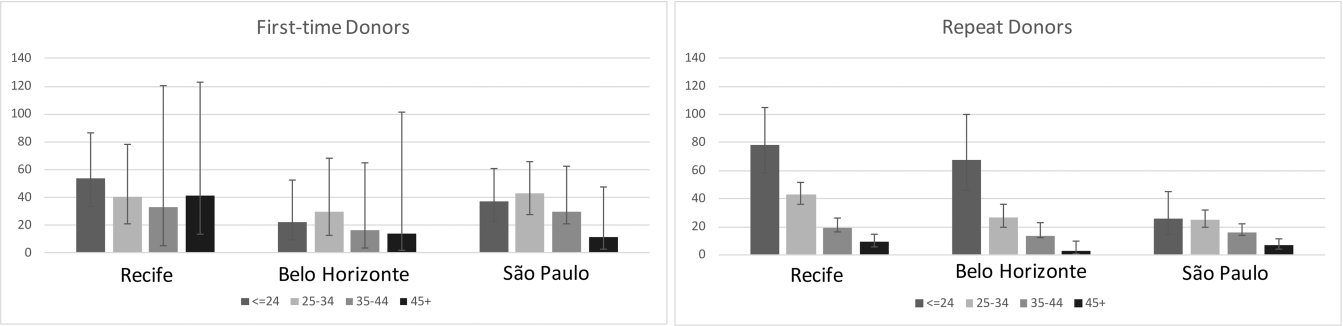

Figure 2.

Comparison of HIV Incidence per 100,000 Person Years and 95% Confidence Interval by Age and Blood Center for First-Time (FTD) and Repeat Donors (RD), 2007 to 2016

Table 1

Characteristics of the 2,544,352 donations by First-time and Repeat donors, 2007 to 2016.

	First-time Donor[a]		Repeat Donor	
Characteristics	**Number of donations**	**%**	**Number of donations**	**%**
Overall	930,180		1,614,172	
Blood Center				
Recife	326,177	35.1	585,249	36.**2**
Belo Horizonte	230,259	24.8	330,413	20.5
São Paulo	373,744	40.**1**	698,510	43.3
Type of donation				
Community	471,917	50.7	1,188,359	73.**6**
Replacement	458,263	49.3	420,869	26.**1**
Missing[b]	**0**	**0**	**4,944**	**0.3**
Age (years)				
≤24	332,206	35.7	213,933	13.3
25–34	334,699	36.0	556,059	34.5
35–44	161,381	17.3	462,075	28.**6**
≥ 45	101,894	11.0	378,211	23.**4**
Missing	0	0	3,894	0,2
Sex				
Female	400,634	43.1	431,776	26.7
Male	529,546	56.9	1,182,396	73.3
Year				
2007–2008	186,128	20.0	318,099	19.7
2009–2010	191,392	20.6	339,138	21.0
2011–2012	194,300	20.9	331,319	20.5
2013–2014	194,330	20.9	317,548	19.7
2015–2016	164,030	17.6	308,068	19.1

[a] First-time donors included in the analysis are donors with no previous donation screening data at the participating blood centers.

[b] Repeat donor are those with two or more donations in each two-year estimation interval. Each donor only contributes person-time to those intervals where he or she made two or more donations.

Table 2

HIV Incidence per 100,000 Person Years and 95% Confidence Interval (CI) by characteristics for First-time and Repeat donors, 2007 to 2016

Characteristics	Recife	95% CI	Belo Horizonte	95% CI	São Paulo	95% CI	Rio de Janeiro	95% CI
First-Time Donors								
Time interval								
All years[a]	45.1	34.4–59.2	23.3	14.9–36.6	32.2	24.2–42.9	N/A[b]	N/A
2007–08	34.2	14.4–81.3	19.6	6.3–60.9	26.6	13.3–53.2	N/A	N/A
2009–10	63.1	34.2–116.3	36.3	16.3–80.9	17.3	7.2–41.5	N/A	N/A
2011–12	34.8	13.8–87.6	31	10.4–92.7	37.2	20.6–67.1	N/A	N/A
2013–14	57.5	25.5–129.9	18.8	0.6–561.6	59.8	37.2–96.1	36.14	17.2–75.8
2015–16	35.5	15.3–82.2	11.4	2.8–45.5	20.9	9.4–46.4	45.87	23.8–88.2
Type of donation								
Community	64.0	40.6–100.8	38.9	19.7–76.8	37.7	27.7–51.4	N/A	N/A
Replacement	34.8	20.0–60.6	13.8	5.8–32.9	17.6	8.4–36.9	N/A	N/A
Age (years)								
≤24	53.8	33.7–86.1	22.1	9.3–52.5	37.2	22.8–60.7	N/A	N/A
25–34	40.9	21.3–78.6	29.5	12.7–68.4	43.2	28.1–66.2	N/A	N/A
35–44	33.0	9–120.7	16.3	4.1–65	29.7	14.2–62.4	N/A	N/A
≥ 45	41.0	13.7–122.7	14.3	2–101.7	11.9	3–47.4	N/A	N/A
Sex								
Female	20.6	8.2–52	7.5	2.4–23.2	11.4	5.7–22.9	N/A	N/A
Male	57.5	39.2–84.2	38.8	21.2–70.9	51.4	37.5–70.3	N/A	N/A
Repeat Donors								
Time interval								
All years	33.2	26.0–42.3	27.5	19.2–39.4	17.0	12.4–23.2	N/A	N/A
2007–08	34.9	20.7 – 58.9	17.5	6.6 – 46.7	24.8	14.1 – 43.6	N/A	N/A
2009–10	37.2	22.4 – 61.7	36.5	19 – 70.1	10.4	4.3 – 24.9	N/A	N/A
2011–12	18.2	8.7 – 38.1	17.7	6.7 – 47.2	25.8	14.7 – 45.5	20.9	8.7 – 50.3
2013–14	33.7	19.6 – 58	40.4	20.2 – 80.8	18.4	9.2 – 36.8	43	21.5 – 86.1
2015–16	41.5	25.5 – 67.8	26.1	10.9 – 62.7	4.6	1.2 – 18.5	25.5	9.6 – 68.1
Type of donation								
Community	37.7	31.3 – 45.4	27.9	21.6 – 36	17.5	14.7 – 20.8	N/A	N/A
Replacement	24.8	20.7 – 29.8	13.3	8.7 – 20.1	8.1	3.4 – 19.4	N/A	N/A
Age (years)								
≤24	78.2	58.4 –	67.8	45.8 – 100.3	25.5	14.5 – 44.9	N/A	N/A
25–34	42.9	35.8 – 51.4	26.2	19.3 – 35.8	24.8	19.3 – 31.8	N/A	N/A
35–44	19.6	14.7 – 26.1	13.8	8.4 – 22.5	16.2	11.9 –22	N/A	N/A
≥45	9.5	6 – 14.8	2.4	0.6 – 9.5	6.9	4.2 – 11.3	N/A	N/A
Sex								
Female	17.2	11.6 – 25.7	8.6	5 – 14.9	6.3	4 – 9.9	N/A	N/A

Characteristics	Recife	95% CI	Belo Horizonte	95% CI	São Paulo	95% CI	Rio de Janeiro	95% CI
Male	32.6	28.4 – 37.4	29.3	23.2 – 37	23.3	19.3 – 28	N/A	N/A

[a] Overall estimates for first-time donors using weighted averages

[b] N/A - HIV-positive first-time blood donations in Rio de Janeiro were analyzed only between the years 2013–2016 and for repeat donors were analyzed between 2011–2016

Table 3

Multivariable analysis of the HIV incidence of First-time (FTD) and Repeat donors (RD), 2007 to 2016

Characteristics	First-time Donor			Repeat Donor		
	IRR[a]	Wald 95% CI	*p value*	IRR	Wald 95% CI	*p value*
Blood Center						
Recife	1.30	0.84 to 2.01	*0.24*	**1.91**	**1.25 to 2.93**	***< 0.01***
Belo Horizonte	0.76	0.42 to 1.36	*0.35*	1.60	0.98 to 2.61	*0.06*
São Paulo	1			1		
Type of donation						
Community	**2.39**	**1.54 to 3.70**	***< 0.01***	**1.78**	**1.16 to 2.74**	***< 0.01***
Replacement	1			1		
Age (years)						
≤24	1.67	0.74 to 3.72	*0.21*	**6.76**	**2.94 to 15.57**	***< 0.01***
25–34	1.79	0.80 to 3.98	*0.15*	**6.64**	**3.05 to 14.48**	***< 0.01***
35–44	1.24	0.50 to 3.06	*0.64*	**3.63**	**1.60 to 8.24**	***< 0.01***
≥ 45	1			1		
Sex						
Female	**0.24**	**0.14 to 0.41**	***< 0.01***	**0.31**	**0.18 to 0.54**	***< 0.01***
Male	1			1		
Year						
2007–2008	0.85	0.42 to 1.72	*0.66*	1.03	0.59 to 1.78	*0.92*
2009–2010	1.18	0.61 to 2.27	*0.61*	1.04	0.60 to 1.82	*0.88*
2011–2012	1.08	0.55 to 2.10	*0.81*	0,90	0.50 to 1.62	*0.73*
2013–2014	1.60	0.86 to 2.97	*0.13*	1.21	0.69 to 2.10	*0.50*
2015–2016	1			1		

[a]Incidence rate ratio in the groups compared to the reference group designated by the 1 value

Table 4

Residual risk estimate per 1 million donations for 2015 to 2016 and Risk-day equivalents per day for all centers combined

	Residual Risk Point Estimate (range) transmission/ million transfusions	Risk-day equivalents Point Estimate (range) infectious window period/days
RBC (20 mL)	5.46 (3.07–8.47)	7.96 (6.54–9.38)
FFP (200 mL)	7.41 (4.41 – 11.03)	10.79 (9.38 – 12.21)