Social and behavioral characteristics of male blood donors and their sexual partners: an analysis to define risk subsets

Tassila Salomon [1,2] Isabel Gomes,[3] Mina Cintho Ozahata,[4] Carlos Henrique Valente Moreira,[5] Claudia Di Lorenzo Oliveira,[6] Thelma T. Gonçalez,[7] Maria Esther Duarte,[8] Carolina Miranda,[1] Anna Bárbara Carneiro Proietti,[1] Ester Sabino,[2] Cesar de Almeida Neto,[9,10,] and Brian Custer,[7,*] For the NHLBI Retrovirus Epidemiology Donor Study-II (REDS-II), International Component*

BACKGROUND: Men who have sex with men in Brazil are deferred from donation for 1 year since their last sexual contact. Legal proceedings in front of the Brazilian Supreme Court could compel blood collection agencies to discontinue use of sexual orientation questions.

METHODS: Data from male participants in a completed HIV risk factor case-control study were used to evaluate whether it is possible to differentiate donors at lower and higher risk for HIV using two analytical approaches: latent class and random forest analyses.

RESULTS: Male blood donors were divided into three distinct risk profile classes. Class 1 includes donors who are heterosexual (96.4%), are HIV negative (88.7%), have a main partner (99.4%), and practice unprotected sex (77.8%). Class 2 includes donors who are men who have sex with men /bisexuals' (100.0%), are HIV positive (97.4%), and were not aware of their sexual partners' HIV status (80.3%). Class 3 includes donors who are heterosexual (84.1%), practice unprotected vaginal/anal heterosexual sex (66.8% vs. 40.9%), and were both HIV positive and HIV negative (49.5% vs. 50.5%). We also found that asking donors about their partner(s)' HIV serostatus could replace asking about donors' sexual orientation and types of partners with relatively minor shifts in sensitivity (0.76 vs. 0.58), specificity (0.89 vs. 0.94), and positive predictive value (0.85 vs. 0.88).

CONCLUSION: Sexual orientation questions on the donor questionnaire could be replaced without great loss in the sensitivity, specificity, and positive predictive value. Social and sexual behaviors of donors and their partners are proxies for HIV risk and can help to develop modified questions that will need controlled trials to be validated.

Regulations governing blood donation and transfusion in Brazil are very similar to those in the United States and Europe, and internationally accepted procedures and guidelines are used as reference in the development of Brazilian rules and practice guidelines. However, the risk of HIV transmission by blood transfusion

ABBREVIATIONS: ACASI = audio computer-assisted structured interview; IVDU = intravenous drug user; LCA = latent class analysis; MSM = men who have sex with men; PPVs = positive predictive values.

From the [1]The Department is GDTC (Technical-Scientific Development Management), Hemominas, the [3]Faculdade Ciências Médicas, the [6]Federal University of Minas Gerais, Belo Horizonte, Minas Gerais; the [2]Institute of Tropical Medicine, the [4]Department of Infectology, University of São Paulo, the [5]Institute of Infectology Emílio Ribas, the [9]Head of the Department Immunhematology Quality Control, Fundação Pró-Sangue - Hemocentro de São Paulo, the [10]Disciplina de Ciências Médicas da Faculdade de Medicina da Universidade de São Paulo, São Paulo, São Paulo; the [8]Department of Hemotherapy Technical Coordinationno, Hemorio, Rio de Janeiro, Brazil; and the [7]Vitalant Research Institute and University of California San Francisco, San Francisco, California.

Address reprint requests to: Tassila Salomon, Itajubá 1851/204, Sagrada Familia, Belo Horizonte, Minas Gerais, 31030-430, Brazil; e-mail: tassilasalomon@gmail.com.

*These authors share the senior authorship for this paper.

This study was funded by a grant from a partnership from University of California in San Francisco and the Vitalant Foundation, San Francisco, CA. It is also part of a PhD project financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001".

Article corrected on June 13, 2019, after first online publication: Figure 2 was updated.

Received for publication March 28, 2019; revision received May 15, 2019, and accepted May 16, 2019.

doi:10.1111/trf.15388

TRANSFUSION 2019;59;2584–2592

persists in Brazil and remains higher than in the United States and most European countries.[1]

As in Australia, Canada, the United States, and several European countries, the Brazilian Ministry of Health changed the regulation for permanent deferral from donation for men who have sex with men (MSM) to a 1-year deferral since their last sexual contact.[2,3] In the United Kingdom, MSM donation deferral is now 3 months after the last sexual contact. Countervailing to the easing of policies, Spain is considering changing their MSM nondeferral policy to a temporary deferral based on individual risk assessments due to the potential risk. In Brazil, there are proceedings in front of the Supreme Court at this time that would compel all blood collectors in the country to change some predonation interview criteria, including not allowing blood centers to ask donors whether their sexual partners are the same or opposite sex or inquiring about other aspects of the donors' sexual partners. There are no available data to understand what possible alternative questions would be appropriate to reduce the risk of donation by people at high risk for infection.

HIV/AIDS is a global epidemic that is dynamic and changing, so the risk is not evenly distributed, varying by risk profile.[4,5] While the routes of HIV infection acquisition are known, the contextual factors, such as how and where people meet their sexual partners, sexual attitudes, and the impact of the numbers and different types of partners, are less well known. Several studies of risk factors for HIV infection conducted in the Brazilian population report sexual transmission as the main cause of cases of HIV/AIDS, with most cases attributed to unprotected sex between MSM. However, there are also other routes of acquisition observed in Brazil, including intravenous drug use and unprotected heterosexual sex.[6] Risk factor studies in blood donors have shown that MSM remains the strongest determinant of HIV status among HIV-positive blood donors.[1,6–9]

We analyzed data from an HIV behavioral risk factor case-control study from the Retrovirus Epidemiology Donor Study–II (REDS-II) to assess whether it is possible to identify high-risk behaviors among HIV-positive donors and their partners and to assess alternative questions that could predict if a blood donor is at risk of being HIV positive, regardless of sexual orientation. Our study sought to assess whether surrogate risk behavior questions can predict if a blood donor is likely to be HIV positive or negative. Additionally, the social and sexual behavior of blood donors and their partners were also evaluated to better understand risk behaviors for HIV infection.

MATERIALS AND METHODS

Study description and sites

The REDS-II HIV case-control study was conducted from April 2009 to March 2011 in four large Brazilian blood centers: Fundação Pró-Sangue in São Paulo, Fundação Hemominas in Belo Horizonte, Fundação Hemorio in Rio de Janeiro, and Fundação Hemope in Recife. More details about the original study design and methods for participant selection, testing, and interview procedures can be found in previously published papers.[6–8] Together, there are nearly 600,000 blood donations, or 15% of all blood donations in Brazil, given to these four blood centers per year. These four Brazilian hemocenters have a wide geographic distribution, are diverse in the socioeconomic characteristics of the donor base, and are located in regions with high rates of HIV. In 2016, 44% of the new HIV infections of the country occurred in these regions.[10]In this analysis, we focused on the risk behavior questionnaire responses for males because of 1) differences in behavior between males and females observed in previous analyses, 2) the fact that the majority of blood donors are male at these blood centers sites, and 3) the focus of the donor eligibility debate in Brazil being on male donors.

Analysis overview

A cross-sectional latent class analysis (LCA) was used to identify patterns of behavior based on the participants' as well as their sexual partners' characteristics. LCA was performed to identify latent population subgroups defined by distinct behavior patterns on multiple risk factors. In this analysis, LCA provides a multidimensional description of how risk factors may work together to increase or decrease the likelihood of acquiring HIV, using methods similar to those reported in other LCAs.[11] Random forest classifiers are an intuitive and interpretable method for data classification.[12] The generated algorithm enables the estimation of each variable's contribution to classification performance by permutation. The random forest analysis was used to define which questions could better predict if a blood donor has higher or lower risk of being HIV positive.

HIV case–control study

Questionnaire and measures

In the original case-control study, the risk behavior questionnaire was implemented using an audio computer-assisted structured interview (ACASI) conducted in a private setting. ACASI was chosen to maximize reporting of potentially stigmatizing behaviors.[13] In the LCA and decision tree analyses, we included sexual orientation based on the behavior reported during the past 12 months. Donors were defined as heterosexual if the participant did not report any same-sex partner, MSM/bisexual if the participant reported having had at least one same-sex partner, or if the donor self-declared MSM or bisexual. The number of sexual partners in the past 12 months was grouped as 0 to 1, 2 to 5, or 6 or more. For the analysis, responses of "do not know" and item response refusals were considered as missing. Participant demographics included age in years, education, and marital status. Variables that identified the blood center (Fundação Pró-Sangue, Hemominas, Hemorio, and Hemope) and the HIV

status of the blood donors were included. HIV-positive blood donors were tested by two enzyme immunoassays and confirmed by western blot, and the HIV-negative blood donors were negative for all the screening serologic markers for infectious diseases applied by the blood centers, including hepatitis C virus, hepatitis C virus, human T-lymphotropic virus-1/2, syphilis, and *Trypanosoma cruzi*.

Sexual matrix

The characteristics of the sexual partners were assessed as binary (yes/no) responses for respondent's self-report on up to five sexual partners in the year before donation. Questions captured age disparity in sexual partnerships of ≥10 years for ≥1 partners, type of partners (main partner, friend, acquaintance, one time, anonymous, sex worker), intravenous drug user (IVDU, if donor was an ever IVDU or had a partner who was an ever IVDU), MSM partner, and if the respondent knew the HIV status of his partners. We also evaluated the venues where each respondent met his partners. In addition, we asked about unprotected vaginal or anal intercourse. Response categories are NOT mutually exclusive, since any blood donor who had more than one partner may have had different sexual behaviors or partners with different characteristics.

Statistical analysis

Latent class analysis

We tested models with two to four latent classes. The results are presented with the distribution of respondent and partner characteristics according to the classes obtained by the best-fit model. The analysis was performed using computer software (poLCA package[14] of R software version 3.4.3) and a significance level of 5% was used.

Random forest

In this analysis, variable importance was calculated following the construction of a random forest with variables listed in Table 1. Additionally, random forests were generated by removing variables, and accuracies, sensitivities, specificities, positive predictive values (PPVs) were compared. A subsetting of the HIV-negative subjects was used to balance class size and avoid classification bias.[15]

Ethical considerations

The case-control study was reviewed and approved by ethical committees in Brazil and institutional review boards in the United States. Specific approval for this secondary data analysis was not obtained because the data set was deidentified.

TABLE 1. Descriptive analysis for the 838 male blood donors from four large Brazilian blood centers from 2009 to 2011

Characteristics	Valid n (n = 838)	Frequency n (%)
Donor's characteristics		
Age (y)	838	33.6 ± 9.9
Educational level	833	
Illiterate/Inc. Elementary school/adult literacy		86 (10.3)
Complete elementary/ high/technician school		596 (71.5)
Graduation/MD/PhD		151 (18.1)
Marital status	838	
Married/Living with		433 (51.7)
Unmarried		405 (48.3)
Sexual history	812	
Heterosexual		618 (76.1)
MSM/Bisexual		194 (23.9)
Lifetime number of partners	838	
0-1		243 (29.0)
2-5		250 (29.8)
≥6		345 (41.2)
Center ID	838	
Fundação Pró-Sangue, São Paulo		242 (28.9)
Hemominas, Minas Gerais		159 (19.0)
Hemope, Pernambuco		175 (20.9)
Hemorio, Rio de Janeiro		262 (31.3)
Characteristics of the last five partners*		
Partner's age		
Age disparity of ≥10 years for ≥1 partners	799	78 (9.8)
Type of partner		
Main partner	799	599 (75.0)
Friend partner	799	133 (16.6)
Acquaintance partner	799	132 (16.5)
One-time partner	799	102 (12.8)
Anonymous partner	799	82 (10.3)
Sex worker partner	799	15 (1.9)
Anonymous or sex worker partner	799	93 (11.6)
Intravenous drug user (IVDU)†		
IVDU or partner IVDU	799	31 (3.9)
Partner's MSM		
Yes	799	104 (13.0)
Partner's HIV status		
Do not know partner's HIV status	799	286 (35.8)
HIV-positive partner	799	32 (4.0)
Venue where met their partners		
Bar or carnival	799	160 (20.0)
Street, park, library, public transportation	799	144 (18.0)
Social/political parties in clubs or church	799	239 (29.9)
Dating service (Internet/newspaper ads)	799	87 (10.9)
Some other way or work	799	374 (46.8)
Unprotected sexual intercourse		
Unprotected vaginal sex	799	533 (66.7)
Unprotected heterosexual anal sex	797	217 (27.2)

* Partner's characteristics were based on the criteria of having at least one partner with such characteristic.
† IVDU was defined as lifetime intravenous drug users or lifetime sexual partners of intravenous drug users.

RESULTS

The REDS-II Brazil HIV case-control study population includes 838 male respondents whose data were used in this analysis. Descriptive statistics for all of the 838 male donors, including the subset of 799 with ACASI questionnaire responses, are provided (Table 1). Respondents had a mean age of 33.6 years, 596 (71.5%) completed elementary school, 433 (51.7%) were

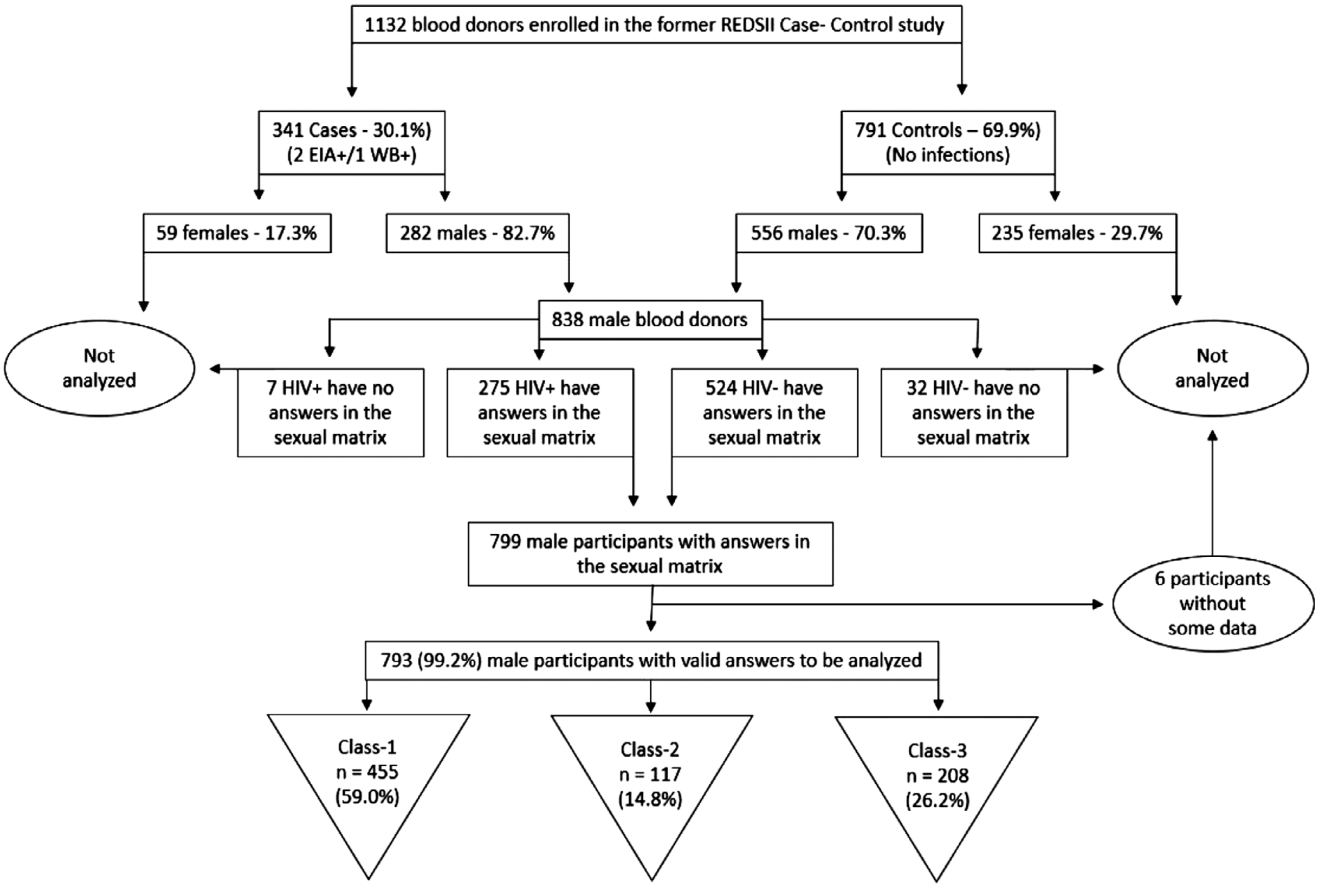

Fig. 1. Flowchart showing the enrollment since the beginning of the former REDS-II case-control study until the selection of the male sample for the analysis performed in the present study.

married, and 666 (79.5%) reported heterosexual partnerships in the past 12 months, and 90 (10.7%) reported having six or more partners in the past 12 months. Of the 799 subset donors, 793 answered the questions from the sexual matrix on their recent sexual partners (Fig. 1). About 10% had at least one partner with a 10 or more years' age difference. Most of blood donors reported having a main partner (75.0%). Four percent reported being an IVDU or a sex partner of an IVDU. Thirteen percent reported having at least one MSM partner among the last five partners. More than one-third (35.8%) reported that they did not know about their partner's HIV status, and 4.0% answered that they had at least one HIV-positive partner in the past 12 months. Thirty percent of the respondents disclosed that they met their partner(s) at social/political events, clubs, or church. More than two-thirds (66.7%) reported an unprotected vaginal sexual encounter, and more than one-quarter (27.2%) reported unprotected heterosexual anal sex with at least one of the last five partners in the past 12 months.

Latent class analysis

There were no substantial differences between 3- or 4-class models, so based on parsimony we chose the 3-class model. The demographic characteristics of blood donors according to three classes are described (Table 2). Also, the last five partnership characteristics are shown in Table 3. Class 1 was the largest, with 59.0% of the sample having the probability of being in this class and was represented by older donors (median 35.7 $\pm$ 9.8 years), who were heterosexual (96.4%) and married (70.9%). The majority (88.7%) of Class 1 blood donors were HIV negative. Compared to the other classes, Class 2 was younger (28.8 $\pm$ 7.5) and unmarried blood donors (77.8%), who reported having at least one MSM partnership (100%), and two-thirds of the individuals of this class (65.8%) had six or more sex partners in the past 12 months. HIV-positive donors make up 98% of this class. Class 3 is represented by primarily heterosexual individuals (84.1%), who reported six or more sexual partners (44.7%), and 33 (15.9%) donors who were MSM. Class 3 is almost equally represented by HIV-positive (50.5%) and -negative (49.5%) donors; however, the majority of HIV-positive donors reported male-male sex (63.6%; data not shown in tables). Table 3 shows a comparison of demographic characteristics, use of illicit drugs, venues where partners were met, and sexual practices with their partners among the three classes. Donors from Class 1 had a significantly higher

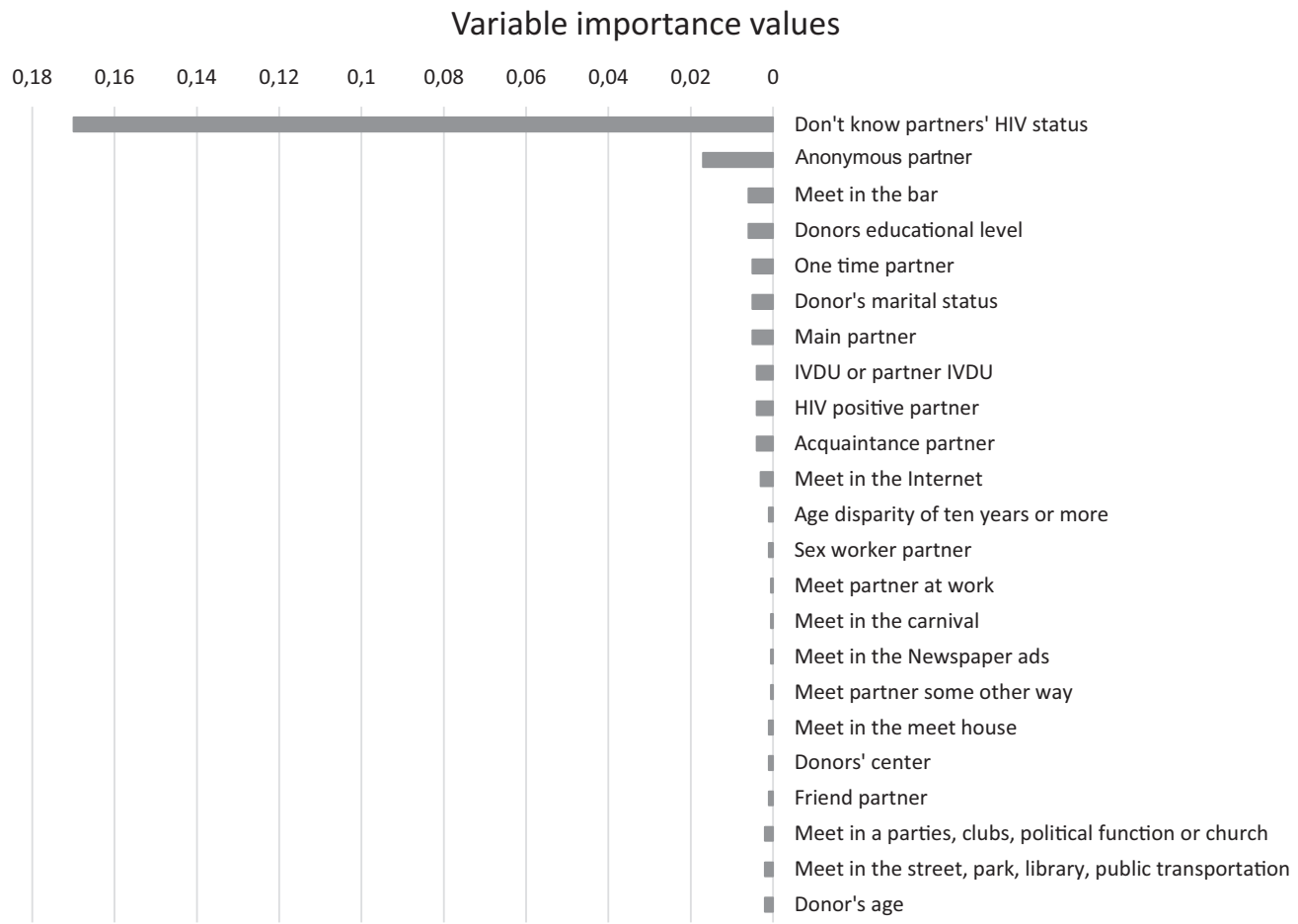

Fig. 2. Random forest graphic showing the variable importance chart, including all 838 HIV positive and negative male blood donor's answers for the sociodemographic and social matrix question, but removing the variables about "sexual orientation."

chance of having a main sex partner (99.4%) and to have had at least one unprotected vaginal sex encounter (77.8%). Class 2 was characterized by those donors who reported having had at least one partner with 10 years or more difference in age (34.2%) and having had at least one anonymous or sex worker partner (40.2%). About 80% of the individuals in Class 2 disclosed that they did not know their partner(s)' HIV status, while 17.1% had at least one known HIV-positive partner. Almost half of those in the Class 2 reported meeting their partners in a bar or at a carnival (46.2%), and more than two-thirds (36.8%) met partners using an online dating app or service (Internet/ads). Class 3 was defined by those donors who had at least one unprotected vaginal and/or anal heterosexual intercourse encounter (66.8% and 40.9%, respectively).

Random forest analysis

The random forest result showed that with all variables we analyzed (listed in Table 4), the sensitivity of these questions would be 0.76, while the specificity would be 0.89. The PPV of this set of questions to identify HIV-positive donors during the predonation interview is 0.85. When we removed the questions about classification of partner type (main, acquaintance, etc.) these values did not change. When we removed questions about sexual orientation, the values of sensitivity, specificity, and PPV decreased (to 0.69, 0.84, and 0.78, respectively). When we removed both questions about partner type and sexual orientation together, the sensitivity decreased (0.67), but the specificity and PPV remained similar (0.84 and 0.78, respectively). The most important question to predict whether a donor is HIV positive in all models is knowing the HIV status of their sexual partner(s), as we can see in figure 2. When this question was removed, we found the lowest sensitivity (0.58).

DISCUSSION

We evaluated blood donors who tested positive and negative for HIV in blood centers from four locations in Brazil. LCA revealed three classes, with distinct levels of risk behavior. Two classes (1 and 2) with differing HIV status were well described with dissimilar behaviors, but Class 3, with mixed

TABLE 2. Demographic characteristics, sexual history, number of partners, and HIV status of 793 male blood donors who answered all the social matrix questions, according to the three classes

Characteristics	Class 1 n = 468 (59.0%)	Class 2 n = 117 (14.8%)	Class 3 n = 208 (26.2%)
Age*	35.7 ± 9.8	28.8 ± 7.5	32.1 ± 9.7
Center ID*			
Fundação Pró-Sangue, São Paulo	107 (22.9)	39 (33.3)	81 (38.9)
Hemominas, Minas Gerais	110 (23.5)	17 (14.5)	24 (11.5)
Hemope, Pernambuco	97 (20.7)	30 (25.6)	40 (19.2)
Hemorio, Rio de Janeiro	154 (32.9)	31 (26.5)	63 (30.3)
Educational level*			
Illiterate/Inc. elementary school/adult literacy	45 (9.6)	6 (5.1)	31 (14.9)
Complete elementary/high/technician school	338 (72.2)	75 (64.1)	152 (73.1)
Graduation/MD/PhD	85 (18.2)	36 (30.8)	25 (12)
Marital status*			
Married/living with	332 (70.9)	26 (22.2)	61 (29.3)
Unmarried	136 (29.1)	91 (77.8)	147 (70.7)
Sexual orientation based on the reported sex partners in the past 12 months*			
Heterosexual	451 (96.4)	-	175 (84.1)
MSM/Bisexual*	17 (3.6)	117 (100.0)	33 (15.9)
Number of partners in the past 12 months*			
0-1	142 (30.3)	11 (9.4)	62 (29.8)
2-4	156 (33.3)	29 (24.8)	53 (25.5)
≥6	170 (36.3)	77 (65.8)	93 (44.7)
HIV status*			
HIV negative	415 (88.7)	3 (2.6)	103 (49.5)
HIV positive	53 (11.3)	114 (97.4)	105 (50.5)

* Difference between classes ($p < 0.05$).

behaviors, had the same proportion of HIV positives and negatives. Class 3 is predominantly a group of heterosexual, unmarried donors with multiple sexual partners, who are having unprotected sex. Therefore, a closer look at this group is needed, as almost half of these individuals are potentially eligible blood donors and can return for new donation. Some characteristics of donors' sexual partners such as age, type of partner, and where donors met their partners may directly affect the risk of being HIV positive. Thus, an understanding of respondent's sexual networks may be extremely useful to improve predonation interviews currently used to select eligible blood donors.

In Class 1, most donors reported practicing unprotected sex. However, most also reported having one main partner, explaining why donors in this class are HIV negative. Despite unprotected sex representing a source of HIV risk in many contexts, our study shows that this could be viewed as a protective factor by virtue of its being an indicator of a lower number of sexual partners in Class 1 members when compared to the other classes.[16]

Class 2 was defined by donors who did not know the HIV status of their partners. Previous studies have shown that a large number of HIV-positive people, especially young people, engage in unprotected sex with casual partners with unknown HIV status.[17–19] The HIV status disclosure to sex partners is very complex and influenced by sex, anticipated support, fear of rejection, and sociocultural context such as stigma/rejection.[20] The lack of support and fear of rejection are less likely to occur in individuals with main and steady partners, so probably the type and number of sexual partners also contributed to the disclosure of HIV status. In some settings, HIV-positive people are encouraged or legally expected to disclose their HIV status to their partners as a strategy to reduce HIV transmission.[21,22] Currently, this is not the situation in Brazil. Nonetheless, more studies are needed to understand the influence of knowledge of HIV status on sexual partnerships and what factors influence the disclosure of HIV status. Donors in Class 2 also reported having met their partners through dating services (Internet/ads) or in a bar/carnival, being the only class in which the meeting venue clearly defined the class profile. A recent study pointed out that there are more risky places than others for risk of sexually transmitted infection, and some people gather at these sites to find potential sexual partners. As a cluster, many individuals at risk and who attend these venues constitute the "risk environment" for HIV acquisition.[23] This was evident in our study, even though it was not defined as an objective of the original REDS-II HIV case–control study.

The random forest analysis showed that the sensitivity values would decrease minimally if direct questions about sexual orientation of blood donors were removed from predonation interviews. When we remove questions about sexual history and partner's type together but keep the partner's HIV unknown status in the model, we achieve reasonable values. The knowledge about sexual partner(s)' HIV status followed by other questions were a strong predictor for donors' HIV status. Mathematical models show that HIV status disclosure can directly impact HIV transmission risk and that individuals who disclosure their HIV status are less likely to have multiple sex partners and more likely to use condoms.[24–26] Removal of questions about sexual orientation and type of sexual partners does not entail significant losses in sensitivity,

TABLE 3. Demographic characteristics, drug use, venues and sexual practices with the sex partners* from 793 male blood donors who answered all the social matrix questions, according to the three classes

Partners' characteristics*	Class 1 n = 468 (59.0%)	Class 2 n = 117 (14.8%)	Class 3 n = 208 (26.2%)
Partner's age			
Age disparity of ≥10 years for ≥1 partners	24 (5.1)	**40 (34.2)**†	12 (5.8)
Partner's type			
Main partner	**465 (99.4)**†	65 (55.6)	65 (31.2)
Friend partner	29 (6.2)	41 (35)	61 (29.3)
Acquaintance partner	7 (1.5)	45 (38.5)	80 (38.5)
One time partner	1 (0.2)	36 (30.8)	63 (30.3)
Anonymous or sex worker partner	-	**47 (40.2)**†	46 (22.1)
Intravenous drug user (IVDU)‡			
IVDU or partner IVDU	6 (1.3)	10 (8.5)	15 (7.2)
Partner's MSM	-	**103 (88.0)**†	-
Partner's HIV Status			
Do not know partner's HIV status	56 (12)	**94 (80.3)**†	133 (63.9)
HIV positive partner's	7 (1.5)	**20 (17.1)**†	4 (1.9)
Venue where met their partners			
Meet in the bar/carnival	42 (9.0)	**54 (46.2)**†	63 (30.3)
Meet in the street, park, library, public transportation	59 (12.6)	34 (29.1)	49 (23.6)
Meet in a parties, clubs, political function or church	132 (28.2)	27 (23.1)	79 (38)
Meet in the date service (Internet/newspaper ads)	9 (1.9)	**43 (36.8)**†	34 (16.3)
Meet some other way/work	243 (51.9)	43 (36.8)	85 (40.9)
Unprotected sexual intercourse			
Unprotected vaginal sex	**364 (77.8)**†	27 (23.1)	**139 (66.8)**†
Unprotected heterosexual anal sex	114 (24.4)	17 (14.5)	**85 (40.9)**†

* Partner's characteristics were based on the criteria of having at least one partner with such characteristic.
† Variables that most clearly define the profile classes' profile.
‡ IVDU criteria were defined as lifetime intravenous drug users or lifetime sexual partners of intravenous drug users.

specificity, and PPV of the models to predict whether donors are HIV positive. However, if the question about HIV status of sexual partners was included as a criterion for donor eligibility, the number of deferrals for persons who do not know their sex partner's HIV status could potentially increase to an unacceptably high proportion. A previous study suggests that extensive questioning of blood donors about their sexual behavior may lead to the loss of existing donors who may find the process invasive.[27]

This study has some limitations. The original case-control study included a convenience sample of HIV cases and a probability sample of controls. The behaviors and characteristics of the respondents may or may not reflect all HIV-positive and infection-negative donors in Brazil. We conducted this analysis for males only, and so the same questions may or may not be capable of predicting HIV-infection risk in females. Because of the context of HIV risk and sexual orientation, it was necessary to focus just on male respondents to assess if there are differences within male blood donors and to measure the impact of the possible changes in the deferral policy for MSM in Brazil. In addition, we have generalized our findings for the participants from the four blood centers in Brazil, assuming they are representative of male donors throughout the country. Despite these limitations, this study represents one of few in the field of sexual networks in blood donors and points out that further studies in this domain to guide changes in blood donations selection are necessary.

We conclude that LCA methods can assess the interaction of multiple risk factors that place individuals at different levels of risk for acquiring sexually transmitted infections, including HIV. This type of assessment is not possible with regular regression methods but shows that use of LCA can help to improve clinical screening and blood donor selection. In our study, HIV-positive blood donors have a homogeneous pattern of behavior, with well-known high-risk behaviors. With the exception of the Class 3 profile, with blood donors who are engaged in mixed high- and low-risk behaviors, the study did find compelling results for questions that could reliably differentiate between lower- and higher-risk blood donors, an unresolved challenge in donor selection. A tendency emerging in

TABLE 4. Sensitivity, specificity and positive/negative predictive values in random forest permutation, including all 838 cases and controls male blood donor's answers for the sociodemographic and sexual matrix questions

Measures/permutation	All variables	Without type of partners variables	Without sexual orientation variables	Without both partner's type and sexual orientation variables	Without partner's HIV status
Sensitivity	0.76	0.76	0.69	0.67	0.58
Specificity	0.89	0.89	0.84	0.84	0.94
Positive predictive value	0.85	0.85	0.78	0.78	0.88
Negative predictive value	0.82	0.82	0.77	0.76	0.73

some countries, such as Spain, Italy, and Portugal, is to select blood donors based on individual risk assessments that can include partners with unknown risk behaviors, new or multiple partners, and not to consider just if a sexual partner is of the same or opposite sex.[3,28] We do not know what the impact of this approach would be in Brazilian blood services. Considering that blood donor selection in Brazil is performed via face-to-face interview and based on epidemiologic data about well-known high-risk behaviors, we recognize that it would not be easy to change to other approaches to donor eligibility questioning. Research to understand barriers to such change would need to be completed to ensure that the adequacy of the blood supply would not be adversely affected. Nonetheless, we conclude that direct or indirect questions about sexual orientation used in the selection of blood donors could be replaced by an inquiry into the knowledge about sexual partner's' HIV status. Thus, while this study shows that changes to donor questioning can differentiate between higher- and lower-risk donors, we believe it is premature to move to new donor eligibility questions in Brazil that have not been studied to assess donor comprehension and acceptability.

ACKNOWLEDGMENTS

The authors acknowledge the support of the University of California, San Francisco's International Traineeships in AIDS Prevention Studies and the Blood System Research Institute (BSRI) for their assistance in the preparation of this article. We also thank the blood donors for providing consent and helping the present study. The Retrovirus Epidemiology Donor Study–II (REDS-II), International Component (Brazil) was the responsibility of the following: Blood Centers: Fundação Pró-Sangue/Hemocentro São Paulo (São Paulo)—Ester C. Sabino, Cesar de Almeida Neto, Alfredo Mendrone Jr., Ligia Capuani, and Nanci Salles; Hemominas (Belo Horizonte, Minas Gerais)—Anna Bárbara de Freitas Carneiro-Proietti, Fernando Augusto Proietti, Claudia Di Lorenzo Oliveira, and Carolina Miranda; Fundação Hemope (Recife, Pernambuco)—Divaldo de Almeida Sampaio, Silvana Ayres Carneiro Leão, and Maria Inês Lopes. Data Warehouse: University of São Paulo (São Paulo)—João Eduardo Ferreira, Márcio Oikawa, and Pedro Losco Takecian. US investigators: Blood Systems Research Institute and University of California San Francisco—M.P. Busch, E.L. Murphy, B. Custer, and T. Gonçalez; Coordinating center: Westat, Inc.—J. Schulman, M. King, and K. Kavounis; National Heart, Lung, and Blood Institute—S.A. Glynn.

CONFLICT OF INTEREST

The authors have disclosed no conflicts of interest.

REFERENCES

1. Sabino EC, Gonçalez TT, Carneiro-Proietti AB, et al. Human immunodeficiency virus prevalence, incidence, and residual risk of transmission by transfusions at Retrovirus Epidemiology Donor Study-II blood centers in Brazil. Transfusion 2012;52:870-9.
2. Brasil. Ministério da Saúde. Portaria 158 de 04 de fevereiro de 2016. Redefine o regulamento técnico de procedimentos hemoterápicos.
3. Benjamin RJ, Bianco C, Goldman M, et al. Deferral of males who had sex with other males. Vox Sang 2011;101:339-67.
4. AMd B, EAd C, Szwarcwald CL. AIDS e infecção pelo HIV no Brasil: uma epidemia multifacetada. Rev Soc Bras Med Trop 2001;34:207-17.
5. Jones A, Cremin I, Abdullah F, et al. Transformation of HIV from pandemic to low-endemic levels: a public health approach to combination prevention. Lancet 2014;384:272-9.
6. de Almeida Neto C, McFarland W, Murphy EL, et al. Risk factors for human immunodeficiency virus infection among blood donors in Sao Paulo, Brazil, and their relevance to current donor deferral criteria. Transfusion 2007;47:608-14.
7. Blatyta PF, Custer B, Gonçalez TT, et al. Undisclosed human immunodeficiency virus risk factors identified through a computer-based questionnaire program among blood donors in Brazil. Transfusion 2013;53:2734-43.
8. de Almeida-Neto C, Goncalez TT, Birch RJ, et al. Risk factors for human immunodeficiency virus infection among Brazilian blood donors: a multicentre case-control study using audio computer-assisted structured interviews. Vox Sang 2013;105:91-9.
9. Patavino GM, de Almeida-Neto C, Liu J, et al. Number of recent sexual partners among blood donors in Brazil: associations with donor demographics, donation characteristics, and infectious disease markers. Transfusion 2012;52:151-9.
10. Brasil. Ministério da Saúde (MS). Boletim epidemiológico Aids e DST Brasília: MS; 2017.
11. Alexander J, Rose J, Dierker L, et al. It is complicated: sexual partner characteristic profiles and sexually transmitted infection rates within a predominantly African American population in Mississippi. Sex Transm Dis 2015;42:266-71.
12. Trevor H, Tibshirani R, Friedman J. The element of statistical learning: data mining, inference, and prediction. 2nd ed. New York, Springer: Springerseries in statistics; 2009;xxii: p. 745.
13. Sanchez AM, Schreiber GB, Glynn SA, et al. Blood-donor perceptions of health history screening with a computer-assisted self-administered interview. Transfusion 2003;43:165-72.
14. Linzer DA, Lewis JB. poLCA: An R package for polytomous variable latent class analysis. J Stat Softw 2011;42:1-29.
15. Chen C, Liaw A, L B, editors. Using random forest to learn imbalanced data. Berkeley: University of California; 2004.
16. Boily MC, Baggaley RF, Wang L, et al. Heterosexual risk of HIV-1 infection per sexual act: systematic review and meta-analysis of observational studies. Lancet Infect Dis 2009;9:118-29.
17. Conserve DF, King G. An examination of the HIV serostatus disclosure process among Haitian immigrants in New York City. AIDS Care 2014;26:1270-4.
18. Tassiopoulos K, Moscicki A-B, Mellins C, et al. Sexual risk behavior among youth with perinatal HIV infection in the United States: predictors and implications for intervention development. Clin Infect Dis 2013;56:283-90.

19. Latkin C, Yang C, Tobin K, et al. Social network predictors of disclosure of MSM behavior and HIV-positive serostatus among African American MSM in Baltimore, Maryland. AIDS Behav 2012;16:535-42.
20. Lunze K, Cheng DM, Quinn E, et al. Nondisclosure of HIV infection to sex partners and alcohol's role: a Russian experience. AIDS Behav 2013;17:390-8.
21. Galletly CL, Glasman LR, Pinkerton SD, et al. New Jersey's HIV exposure law and the HIV-related attitudes, beliefs, and sexual and seropositive status disclosure behaviors of persons living with HIV. Am J Public Health 2012;102:2135-40.
22. Vu L, Andrinopoulos K, Mathews C, et al. Disclosure of HIV status to sex partners among HIV-infected men and women in Cape Town, South Africa. AIDS Behav 2012;16:132-8.
23. Young LE, Michaels S, Jonas A, et al. Sex behaviors as social cues motivating social venue patronage among young black men who have sex with men. AIDS Behav 2017;21: 2924-34.
24. Niccolai LM, Dorst D, Myers L, et al. Disclosure of HIV status to sexual partners: predictors and temporal patterns. Sex Transm Dis 1999;26:281-5.
25. Pinkerton SD, Galletly CL. Reducing HIV transmission risk by increasing serostatus disclosure: a mathematical modeling analysis. AIDS Behav 2007;11:698-705.
26. Kalichman SC, Kalichman MO, Cherry C, et al. HIV disclosure and transmission risks to sex partners among HIV-positive men. AIDS Patient Care STDS 2016;30:221-8.
27. Goldman M, Yi QL, Ye X, et al. Donor understanding and attitudes about current and potential deferral criteria for high-risk sexual behavior. Transfusion 2011;51: 1829-34.
28. Suligoi B, Pupella S, Regine V, et al. Changing blood donor screening criteria from permanent deferral for men who have sex with men to individual sexual risk assessment: no evidence of a significant impact on the human immunodeficiency virus epidemic in Italy. Blood Transfus 2013;11:441-8.