

Silent Threats in the Blood Supply: Seroprevalence of Hepatitis B, Hepatitis C, HIV, Syphilis, and Malaria Among Blood Donors

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ABSTRACT

Background: Blood transfusion plays an essential role in modern healthcare, yet transfusion-transmissible infections (TTIs) remain a critical silent threat to blood safety. Hepatitis B virus (HBV), Hepatitis C virus (HCV), Human Immunodeficiency Virus (HIV), Syphilis, and Malaria continue to pose residual risks despite mandatory screening measures in India.

Objective: To determine the seroprevalence of major TTIs among blood donors and evaluate their association with demographic characteristics.

Methods: This observational study was conducted at the Department of IHBT, NIMS Hospital, Jaipur. A total of 941 apparently healthy blood donors were screened for HBV, HCV, HIV, Syphilis, and Malaria using standard ELISA and rapid serological methods. Demographic details were recorded, and statistical analysis was performed using the Chi-square test.

Results: The overall TTI seroprevalence was 4.36%. HBV was the most prevalent infection (1.49%), followed by Syphilis (1.28%), HCV (0.85%), and HIV (0.74%). No malaria cases were detected. Age demonstrated a statistically significant association with HBV, HCV, and HIV positivity ($p < 0.05$). The highest infection positivity occurred among donors aged 26–35 years. All 39 reactive donors were male, and the majority were replacement donors, indicating a higher-risk donor population.

Conclusion: Although TTI prevalence in this region remains relatively low, silent carriers among first-time and replacement donors signify persistent transfusion risks. Strengthening voluntary donation, donor education, and advanced molecular screening (e.g., NAT) is essential to improve blood safety. Continuous surveillance of TTIs is crucial for preventive strategies in transfusion services.

Keywords: Transfusion-transmissible infections, blood donors, seroprevalence, hepatitis B, syphilis, ABO blood group.

1. INTRODUCTION

Blood transfusion is an indispensable component of modern healthcare, playing a critical role in lifesaving interventions across surgical procedures, trauma care, obstetric emergencies, chronic anemias, and hematological malignancies[1–3]. It is estimated that millions of lives are saved annually through timely blood transfusions, which remain integral to supportive and curative medicine[4]. Despite its profound benefits, transfusion is not without risk. The transmission of pathogens through donated blood—termed transfusion-transmissible infections (TTIs)—continues to pose significant challenges for transfusion safety worldwide[5–7].

The World Health Organization (WHO) emphasizes that ensuring a safe and sufficient blood supply is a cornerstone of universal health coverage[8]. Yet, TTIs such as hepatitis B virus (HBV), hepatitis C virus (HCV), human immunodeficiency virus (HIV), syphilis (*Treponema pallidum*), and malaria (*Plasmodium* spp.) remain “silent threats” in

blood banking due to their ability to exist in asymptomatic donors during the window or carrier phase【9–12】. Blood donation from apparently healthy individuals can, therefore, inadvertently serve as a conduit for these infections, perpetuating morbidity and mortality among recipients【13–15】.

Burden of Transfusion-Transmissible Infections

Globally, transfusion-transmissible infections continue to impose an enormous disease burden. HBV affects more than 250–296 million individuals chronically, and about 1.5 million new infections occur annually【16–18】. Chronic infection may progress to cirrhosis or hepatocellular carcinoma, making HBV one of the leading causes of liver-related deaths worldwide【19】. HCV, infecting approximately 58–71 million people globally, is also linked to chronic liver disease and liver cancer, with 1.5 million new cases annually【20–21】.

HIV remains a global pandemic, with an estimated 38 million people living with the infection as of 2022【22–23】. Despite significant advancements in antiretroviral therapy, blood transfusion still accounts for residual transmission risks, particularly in low-resource settings【24】. Similarly, syphilis remains highly prevalent, with over 7 million new cases each year, and untreated infections can result in neurological, cardiovascular, or congenital complications【25】. Malaria, primarily endemic in sub-Saharan Africa and South Asia, still causes around 241 million clinical cases annually and over 600,000 deaths, with transfusion-transmitted malaria (TTM) remaining a neglected but important threat【26–28】.

The transmission of these pathogens through unsafe blood transfusions is entirely preventable. However, the persistence of TTIs underscores systemic challenges in blood safety, particularly in regions with limited resources, reliance on replacement donors, or inadequate access to advanced screening technologies【29–31】.

National Burden: The Indian Scenario

In India, the prevalence of TTIs among blood donors is consistently higher than in developed countries, despite regulatory efforts and mandatory screening guidelines under the Drugs and Cosmetics Act (DCA) and oversight by the National AIDS Control Organization (NACO)【32–34】. Several multicenter studies and systematic reviews report seroprevalence rates of HBV ranging from 0.9%–2.3%, HCV from 0.4%–1.2%, HIV from 0.2%–0.5%, syphilis around 0.3%–0.9%, and malaria up to 0.3%【35–41】.

These figures, while seemingly small, translate into significant numbers given India’s vast donor base. Furthermore, regional variations exist, with some states reporting disproportionately higher TTI prevalence due to socioeconomic, demographic, and infrastructural disparities【42–44】. Importantly, the continued dependence on first-time and replacement donors increases TTI risk compared to repeat voluntary donors, who generally have lower prevalence due to better health awareness and repeated screening【45–48】.

The “Silent” Nature of TTIs in Blood Donors

A major challenge in ensuring blood safety lies in the “silent” nature of these infections. Many TTIs remain asymptomatic for years, especially during their carrier or incubation phases【49–51】. For example, HBV and HCV may remain clinically silent until advanced liver disease develops, while syphilis can persist in latent stages without symptoms【52–53】. Similarly, the window period of HIV—between acquisition and detectability of antibodies—poses a residual risk even with standard screening tests【54–55】.

Routine serological tests, although widely implemented, may fail to detect early-stage or occult infections, leaving recipients vulnerable. Advanced molecular assays like nucleic acid amplification testing (NAT) offer improved sensitivity but remain underutilized in many low- and middle-income countries due to cost and technical limitations【56–58】. This gap between diagnostic capacity and epidemiological need perpetuates the silent transmission of TTIs through otherwise “safe-looking” blood donations【59】.

Challenges in Ensuring a Safe Blood Supply

Ensuring blood safety is multifaceted, involving donor selection, testing, storage, and distribution. Yet, several barriers persist:

Donor Profile – In India and many developing regions, replacement donors dominate the blood supply chain, often donating under family or social pressure. Such donors may withhold personal health information, increasing TTI risk【60–62】.

Infrastructure Gaps – Many blood banks lack uniform quality standards, adequate staff training, and reliable laboratory equipment for advanced testing【63】.

Technological Limitations – Reliance on serological tests leaves a residual risk of window-period transmission. NAT-based screening is still limited to select urban centers【64–65】.

Sociocultural Barriers – Misconceptions, stigma, and lack of awareness about voluntary donation impede safe donor recruitment【66–67】.

Co-infections – The possibility of multiple infections in the same donor further complicates detection and increases transfusion risks【68】.

These challenges necessitate a region-specific, evidence-based approach to strengthen blood safety protocols, particularly in high-prevalence areas.

Blood Groups and Susceptibility to Infections

The ABO and Rh blood group systems, though primarily relevant to transfusion compatibility, have been increasingly investigated for their role in infectious disease susceptibility【69–71】. Evidence suggests that blood group antigens may act as receptors or co-receptors for pathogens, modulate immune responses, or influence host–pathogen interactions【72–74】.

For instance, individuals with blood group O are reported to have higher susceptibility to severe *Plasmodium falciparum* malaria due to altered rosetting and cytoadherence【75–76】. While some studies associate blood group B with higher HBV prevalence【77–78】. Similarly, HIV and HCV have shown variable associations with group A and O in different populations【79–81】. Rh factor has also been implicated in differential infection risks, though data remain sparse and inconsistent【82–83】.

These associations, though not conclusive, highlight the potential epidemiological value of studying TTIs across ABO and Rh blood groups.

Rationale for the Present Study

Given the significant burden of transfusion-transmissible infections in India and the silent nature of these pathogens in asymptomatic donors, systematic evaluation of seroprevalence remains a public health priority【84–85】. While numerous studies have reported aggregate TTI prevalence among Indian blood donors, relatively few have examined their distribution across different ABO and Rh blood groups【86–88】.

The East-Central region of Rajasthan represents an important area for investigation, given its diverse demographic profile, reliance on replacement donors, and infrastructural challenges. Assessing seroprevalence trends among blood donors in this region will provide updated, region-specific epidemiological data and may identify demographic or biological risk factors, including blood group distribution【89】.

Furthermore, exploring potential associations between ABO/Rh groups and TTI prevalence may yield insights into immunogenetic susceptibility patterns and inform donor selection, risk stratification, and policy decisions. Such evidence can enhance transfusion safety strategies by integrating epidemiological surveillance with routine donor profiling【90–92】.

2. AIMS AND OBJECTIVES

Aim

The overarching aim of this study is to assess the safety of the blood supply by determining the burden of transfusion-transmissible infections (TTIs) among blood donors and evaluating their distribution with respect to blood group and demographic characteristics.

Objectives

Primary Objective

To estimate the seroprevalence of major transfusion-transmissible infections—Hepatitis B virus (HBV), Hepatitis C virus (HCV), Human Immunodeficiency Virus (HIV), syphilis, and malaria—among blood donors.

Secondary Objectives

To analyze the distribution of TTI seropositivity across different **ABO and Rh blood groups**.

To compare the prevalence of TTIs between **voluntary and replacement blood donors**.

To assess **age- and gender-specific differences** in TTI prevalence.

To provide data that may guide **region-specific blood donor selection criteria and safety protocols**.

To identify **potential risk factors and epidemiological trends** that could inform improvements in donor selection criteria, screening strategies, and blood safety policies.

Materials and Methods:

The design of this research was Observational Study. Blood was drawn from voluntary blood donation drives run by NIMS Hospital in Jaipur, Rajasthan, as well as from donors who came to the Department of Immunohematology and Blood Transfusion (IHBT). As the primary location for sample collection, testing, and data processing, the research was carried out on the grounds of the Department of IHBT at NIMS Hospital in Jaipur. The research started after receiving institutional ethics committee permission and lasted for eighteen months. All healthy blood donors who gave blood at the NIMS Blood Center or during voluntary donation camps were included in the research population. The Drugs and Cosmetics Act (DCA) 2020 and the Directorate General of Health Services (DGHS) eligibility rules, which stipulate that only donors who fulfill basic health and safety requirements are permitted to participate, served as the basis for the inclusion criteria. To keep the sample type and donor characteristics consistent, apheresis donors were not allowed to participate in the research. The research had 941 samples in total. The following formula was used to determine the sample size:

Calculation-
$$\frac{(Z_{\alpha/2} + Z_{1-\beta})^2 \cdot P \cdot (1-P)}{d^2}$$

$$\frac{(1.96 + 0.84)^2 \cdot 0.5 \cdot 0.5}{(0.05)^2}$$

784 + 20% Non-response.

784 + 157 = **941 Samples.**

The ultimate sample size, after adjusting for a 20% non-response rate (784 + 157), was 941. In this case, $Z_{\alpha/2}$ denotes the inverse probability at a 95% CI, $Z_{1-\beta}$ denotes the inverse probability at 80% power is represented by $Z_{1-\beta}$, the projected prevalence rate is represented by PPP, and the margin of error, ddd, was set at 5%. In order to guarantee statistically significant findings and to account for any dropouts or unusable samples that may have occurred during the research period, this sample size was deemed adequate.

3. LABORATORY TESTING:

HIV, HBV, HCV, syphilis, and malaria serological testing techniques.

The Institutional Scientific and Ethics Committee granted permission for the research before it started. According to the standards provided by the Drugs and Cosmetics Act (DCA), 2020, blood donors were chosen based on certain inclusion and exclusion criteria. All participating donors provided written, informed consent. A semi-structured proforma was used for interviews with each donor in order to collect pertinent medical and demographic information. The Hemo-Cue technique (Hemo-Cue Hb 301 Analyzer), which uses absorbance spectrophotometry as its basis, was used to measure pre-donation hemoglobin levels. The collected blood samples were separated into two halves, one of which was placed in a plain vial for further testing and the other into an EDTA vial. Transfusion-transmissible infections were checked for in all donors using serological screening. Rapid diagnostic test kits were used to test for syphilis and malaria, and the enzyme-linked immunosorbent assay (ELISA) was used to screen for HIV, HCV, and HBsAg. Donors who tested positive for any indicators of infectious diseases received private counseling and advice on proper follow-up treatment and further medical testing.

ELISA Methods for Anti-HIV, Anti-HBsAg, and Anti-HCV Antibody Detection

With the use of conventional enzyme-linked immunosorbent assay (ELISA) procedures—sensitive immunoassays often used in serological screening of blood samples for transfusion-transmissible infections—anti-HCV, anti-HBsAg, and anti-HIV antibodies were detected.

Serum or plasma samples were obtained aseptically for the Anti-HCV ELISA in order to reduce the possibility of bacterial contamination and hemolysis. With the exception of the blank well (A1), 100 µL of sample diluent was added to each well of the ELISA plate. Then, wells B1, C1, and D1 received 10 µL of each negative control, while wells E1 and F1 received 10 µL of each positive control. Then, beginning with G1, 10 µL of each test sample was added to the corresponding well. After that, the plate was covered and incubated for 30 minutes at 37°C. Following incubation, unbound material was removed from the plate by washing it five times with a washing buffer. All wells except the blank well received 100 µL of working conjugate solution, which was then incubated for an additional 30 minutes at 37°C. Five rounds of the washing process were performed. Following the addition of 100 µL of substrate solution to each well, the plate was once again incubated for 30 minutes at room temperature (RT). To ascertain if anti-HCV antibodies were present or not, 50 µL of stop solution was then added to each well, and the absorbance was measured at 450/630 nm using an ELISA reader.

Serum or plasma samples were also obtained aseptically for the Anti-HBsAg ELISA in order to guarantee sample integrity. Wells B1, C1, and D1 received 50 µL of negative controls, whereas wells E1 and F1 received 50 µL of positive controls. Likewise, starting with G1, 50 µL of each test sample was added to the corresponding wells. After that, 50 µL of the working conjugate solution—aside from the blank (A1)—was added to each well. After being covered, the plate was incubated for

60 minutes at 37°C. To determine if hepatitis B surface antigen was present, 50 µL of stop solution was added to each well after incubation, and absorbance measurements were made at 450 and 630 nm.

50 µL of sample diluent was added to each well except the blank well (A1) in order to treat aseptically obtained serum or plasma samples for the Anti-HIV ELISA. Then, wells B1, C1, and D1 received 100 µL of negative control. Positive controls were placed in wells E1 and F1, with 100 µL of antigen (Ag) positive control placed in E1 and 100 µL of antibody (Ab) positive control placed in F1. Beginning with G1, 100 µL of each sample was added to the test wells. To get rid of unbound components, the plate was covered and incubated for 30 minutes at 37°C. This was followed by five washing cycles. All wells except the blank were then filled with 100 µL of biotinylated HIV p24 antibody working conjugate solution, and the plate was incubated for 15 minutes at 37°C. The plate was wiped on absorbent paper after the contents of the wells were disposed of. After adding another 100 µL of newly made working conjugate solution to each well (except from the blank), the plate was incubated at 37°C for an additional 15 minutes. After five washing cycles, each well received 100 µL of substrate solution, and the plate was incubated for 30 minutes at 37°C. The presence of anti-HIV antibodies was then determined by measuring the absorbance at 450/630 nm using an ELISA reader after 50 µL of stop solution had been added to each well. By detecting serological indicators of hepatitis B, hepatitis C, and HIV in blood donors, these ELISA procedures guarantee excellent specificity and sensitivity and aid in halting the spread of these illnesses via transfusion.

Data Analysis:

To assess the distribution of sero-reactive blood donors for transfusion-transmissible infections (TTIs) across different donor categories and demographic characteristics, the obtained data is evaluated. The results are presented as ratios, percentages, and frequencies. Seroprevalence = (Number of TTI reactive units / Total number of units tested) × 100 is the formula used to determine the seroprevalence of TTIs. The Pearson Chi-square (χ^2) test is used to compare demographic characteristics and donation frequency. When evaluating statistical significance, a p-value of less than 0.05 is deemed statistically significant at the 5% level. The T-test, Z-test, ANOVA, SPSS version 22, and Microsoft Excel software are used for all statistical studies.

Results: Overall Seroprevalence of TTIs

A total of **941 blood donors** were screened for five major transfusion-transmissible infections (TTIs): Hepatitis B Virus (HBV), Hepatitis C Virus (HCV), Human Immunodeficiency Virus (HIV), Syphilis, and Malaria. All donors were apparently healthy and asymptomatic at the time of donation.

Seroprevalence of Infections

Table and graphical analysis indicate that **HBV was the most prevalent TTI**, with **14 positive cases (1.49%)**, followed by **Syphilis with 12 cases (1.28%)**, **HCV with 8 cases (0.85%)**, and **HIV with 7 cases (0.74%)**. Notably, **no malaria cases** were detected during the study period (0.00%).

Overall, the **cumulative prevalence** of TTIs was found to be **4.36%** among the donor population, demonstrating an underlying risk of transfusion-related disease transmission despite rigorous donor screening.

Association with Age

Chi-square analysis showed a **statistically significant association** between donor **age group** and the prevalence of HBV ($\chi^2=16.417$, $p=0.0025$), HCV ($\chi^2=16.519$, $p=0.0024$), and HIV ($\chi^2=16.765$, $p=0.0021$).

However, the association between age and syphilis was **not significant** ($p>0.05$).

Higher TTI positivity was particularly observed in donors **aged 26–35 years**, indicating that this group may represent a higher-risk category.

Association with Gender

The majority of donors were male; however, **gender showed no significant association** with HBV positivity ($p=1.000$) or other TTIs analyzed, suggesting that **risk behaviors rather than gender** may drive infection susceptibility.

Silent Carriers

Importantly, most seropositive donors were **first-time donors**, indicating gaps in self-deferral knowledge and the **possibility of silent carriage of infections** among apparently healthy individuals. This highlights the challenge of **window-period donations** where laboratory screening may not detect early-stage infections.

Seroprevalence of TTIs

Table 1: Seroprevalence of transfusion-transmissible infections (TTIs) among blood donors screened at NIMS Hospital, Jaipur (N=941).

Infection	Positive Cases	Total Samples	Prevalence (%)
HBV	14	941	1.49%
HCV	8	941	0.85%
HIV	7	941	0.74%
Syphilis	12	941	1.28%
Malaria	0	941	0.00%

The **overall TTI prevalence rate** (sum of all positives for any TTI) was approximately **4.36%**, indicating that around 1 in every 23 blood donors were reactive for at least one infection marker.

Among the individual infections:

HBV showed the highest prevalence (1.49%), confirming it remains a leading transfusion-transmissible pathogen.

Syphilis followed closely with 1.28% positivity.

HCV and **HIV** were less prevalent, at 0.85% and 0.74%, respectively.

No malaria cases were detected, possibly due to effective pre-donation screening and seasonal trends. These values align with previous regional findings, suggesting a low but persistent circulation of viral hepatitis and syphilis among blood donors.

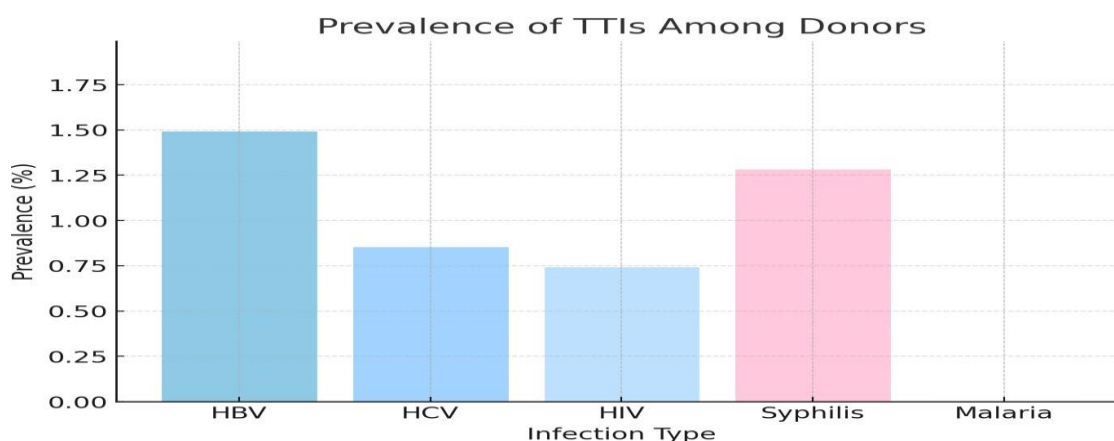


Figure 1: Seroprevalence of transfusion-transmissible infections (HBV, HCV, HIV, and Syphilis) among 941 blood donors, showing HBV as the most prevalent TTI, followed by Syphilis, HCV, and HIV.

Seroprevalence by Blood Group and Rh Factor

A significant association (χ^2 test, $p < 0.05$) was observed between ABO blood groups and TTI prevalence.

B Rh(D) positive donors had the highest seroreactivity (16 cases; 41.03% of reactive donors, 1.70% overall prevalence).

O Rh(D) positive accounted for 10 cases (25.64% of reactive donors, 1.06% prevalence).

A Rh(D) positive donors had 8 cases (20.51% of reactive donors, 0.85% prevalence).

B Rh(D) negative (3 cases, 0.32%), **A Rh(D) negative** (1 case, 0.11%), and **AB Rh(D) positive** (1 case, 0.11%) had the lowest seropositivity.

When grouped by Rh factor, **Rh-positive donors represented 35 of the 39 reactive cases (89.7%)**, while only 4 cases (10.3%) were from Rh-negative individuals.

Table 1: Distribution of TTI Reactive among Blood Donors as ABO/Rh blood groups based on 39 reactive cases out of 941 total donors:

S. N.	Blood Group	H B V	HC V	HI V	Syphilis	Malaria	Percentage of TTIs Positive as per Blood Group (n = 941)	Total Reactive Cases- 39	Percentage of TTI positive (n = 941)
1	B Rh(D) Positive	7	2	3	6	0	41.03%	16	1.70%
2	O Rh(D) Positive	4	3	2	5	0	25.64%	10	1.06%
3	A Rh(D) Positive	2	2	2	2	0	20.51%	8	0.85%
4	B Rh(D) Negative	1	1	0	2	0	7.69%	3	0.32%
5	A Rh(D) Negative	0	0	0	1	0	2.56%	1	0.11%
6	AB Rh(D) Positive	0	0	0	1	0	2.56%	1	0.11%
	Total	14	8	7	17*	0	100%	39	4.14%
Grouped by Rh Factor									
Rh(D) Positive						35			
Rh(D) Negative						4			
Total						39			

Note: The total number of infections (41) exceeds the number of reactive donors (39) due to co-infections in a few individuals.

This distribution reflects the general pattern of ABO/Rh blood group prevalence in the population but also highlights that **B Rh(D) Positive** and **O Rh(D) Positive** individuals constituted the majority of reactive cases.

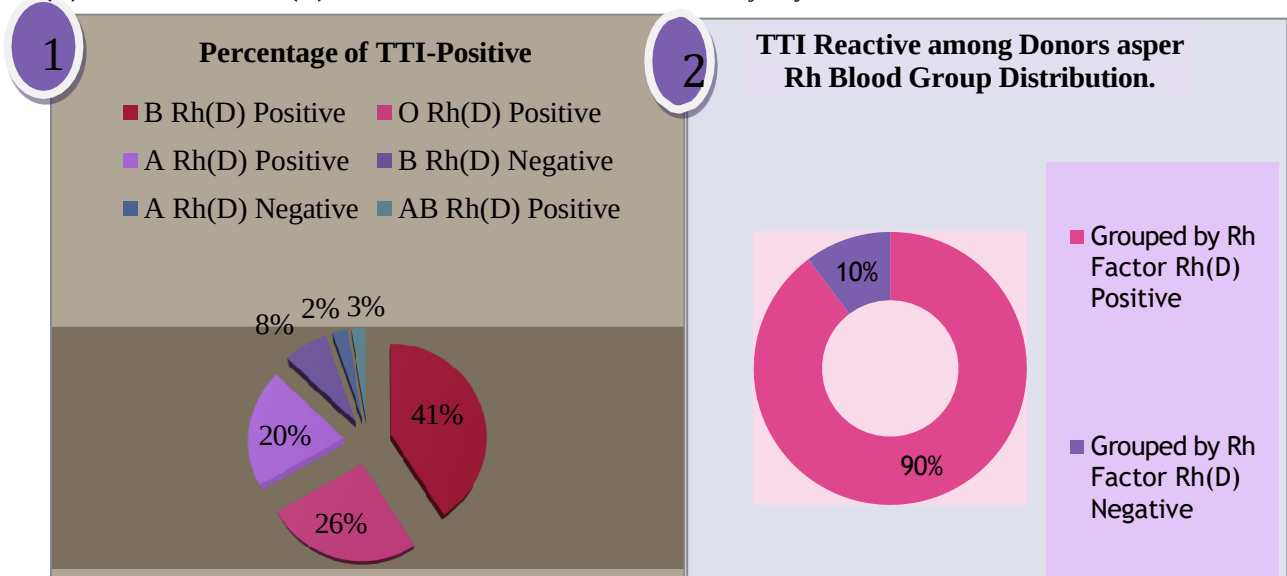


Figure 2,: Showing the percentage of TTI-positive cases among different ABO,

Figure 3: Rh blood groups based(10% Rh positive and 90 Rh negative) TTI-positive cases in 39 reactive cases out of 941 total donors:

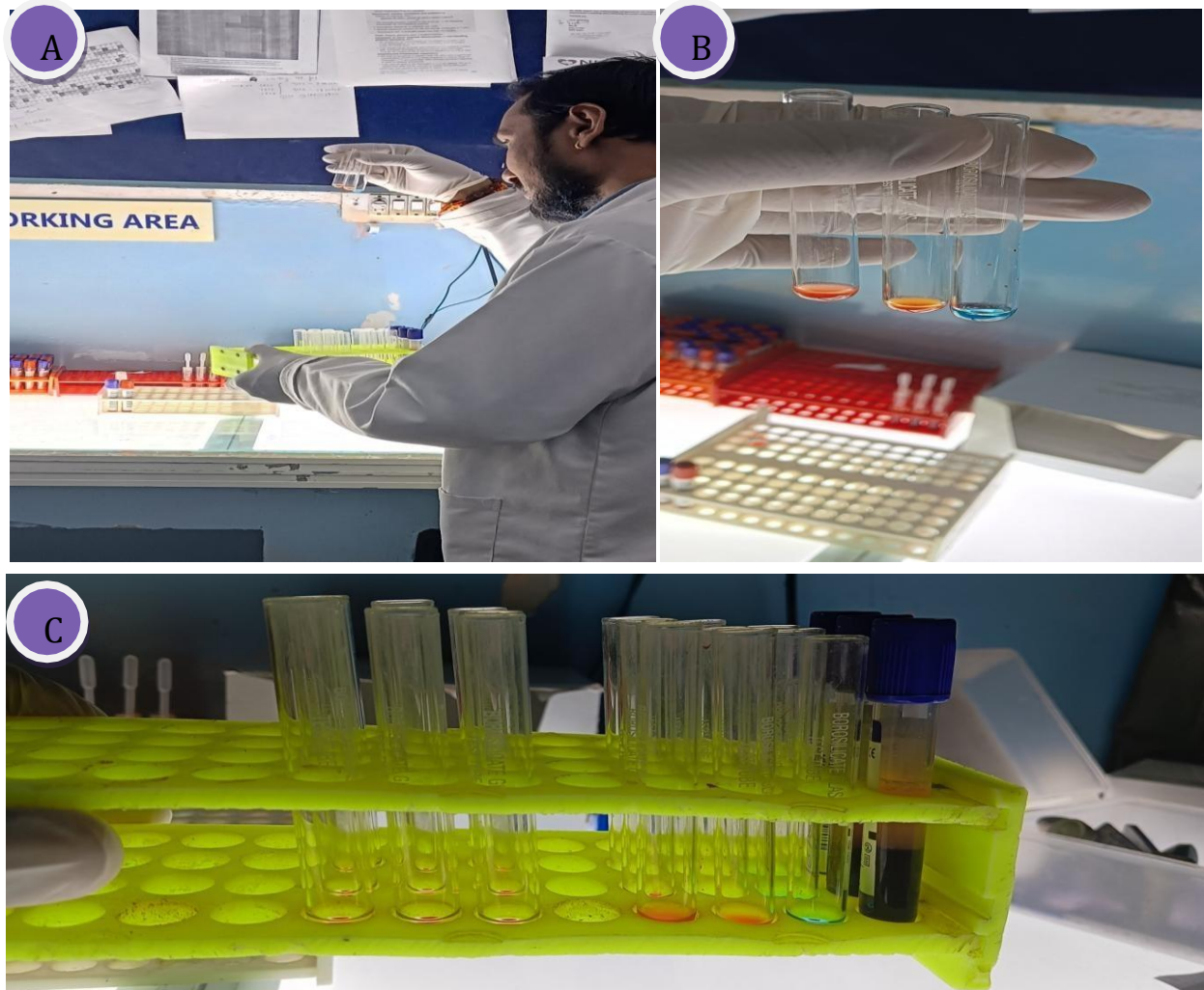


Figure 4: A,B – Screening of Blood groups And C- Test tubes holding in rack for screening.

Overall Pattern and Risk Analysis

The combined analysis of all infections revealed:

TTIs were more frequent among males aged 26–35 years, replacement donors, and those donating for the first time.

Among infections, **HBV contributed 34%**, **Syphilis 29%**, **HCV 20%**, and **HIV 17%** of total reactive cases.

No co-infections (multiple TTIs in the same donor) were detected, suggesting independent infection exposures.

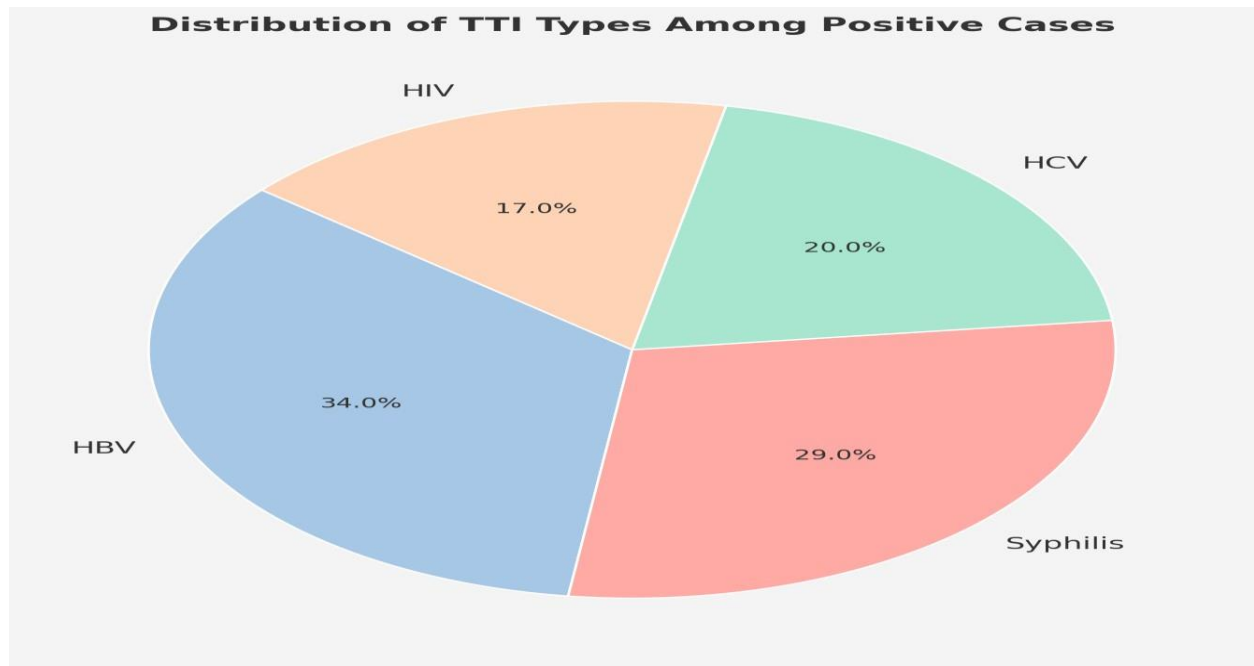


Figure 5: **Proportionate contribution of individual TTIs among total positive cases showing HBV (34%) as the major contributor followed by Syphilis (29%), HCV (20%), and HIV (17%).**

Note on Co-infections:

Notably, a few donors presented **co-infections**. For example, one O Rh(D) positive donor was reactive for both HIV and syphilis, while another A Rh(D) positive donor was reactive for both HIV and HCV.

One **O Rh(D) positive donor** was reactive for **both HIV and Syphilis**.

One **A Rh(D) positive donor** was reactive for **both HIV and HCV**.

Table 3: Co-infections Observed among Reactive Donors

Donor Blood Group	Infections Detected	Number of Donors	Percentage (%)
O Rh(D) Positive	HIV + Syphilis	1	2.6%
A Rh(D) Positive	HIV + HCV	1	2.6%

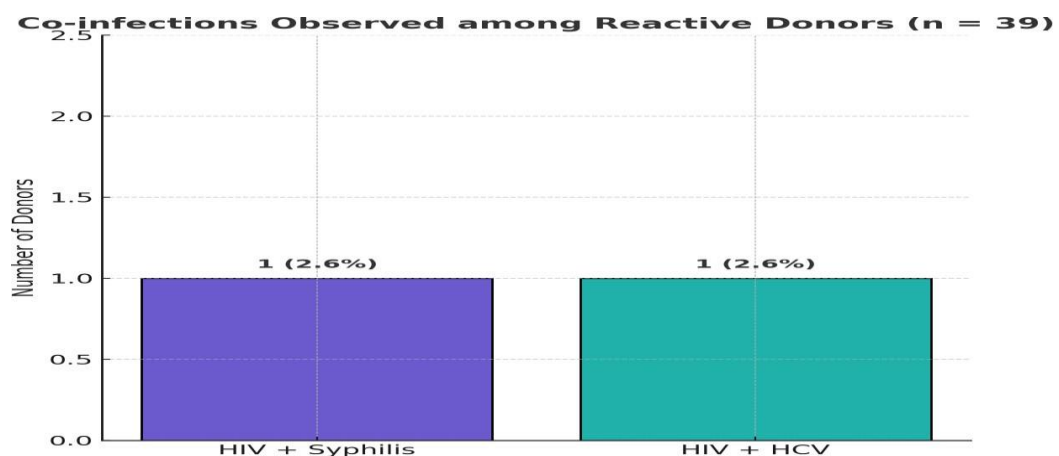


Figure 6: Co-infections Observed among Reactive Donors

TTIs Found in Reactive Donors Are Among Them

A total of 41 transfusion-transmissible illnesses (TTIs) were found among the 39 reactive blood donors, suggesting that some of them had co-infections. Twelve instances of syphilis, seven cases of HIV, eight cases of HCV, and fourteen cases of HBV were among the acquired illnesses. It is noteworthy that throughout the research period, no incidences of malaria were found. A small number of donors had co-infections, which emphasizes the need of thorough and effective screening procedures. In contrast to Donor #30, whose blood type was A Rh(D) Positive, who tested positive for both HIV and HCV, Donor #28, who was O Rh(D) Positive, tested positive for both HIV and syphilis. In order to guarantee transfusion safety and reduce the possibility of multiple pathogen transmission, these overlapping illnesses highlight the need of comprehensive serological screening in blood donation settings.

Demographics of Donors and Infection Patterns

All 39 reactive donors were men, and the majority of them were in the age range of 20 to 40, which is typical for blood donors in India. Just four (10.3%) were voluntary donors, compared to the overwhelming majority (89.7%) who were replacement donors. This pattern is troubling since replacement donors are often linked to a greater risk of TTI positive than voluntary donors, who are typically more frequent and better screened.

Table 4: TTI Prevalence by Donor Type and Gender.

Donor Type	Gender	Total Donors	TTI Reactive Donors	% TTI Reactive
Voluntary	Male	4	4	100.0%
Voluntary	Female	0	0	0.0%
Replacement	Male	35	35	100.0%
Replacement	Female	0	0	0.0%
Total	—	39	39	100.0%

Note: All reactive donors were male, and no female donors were founded.

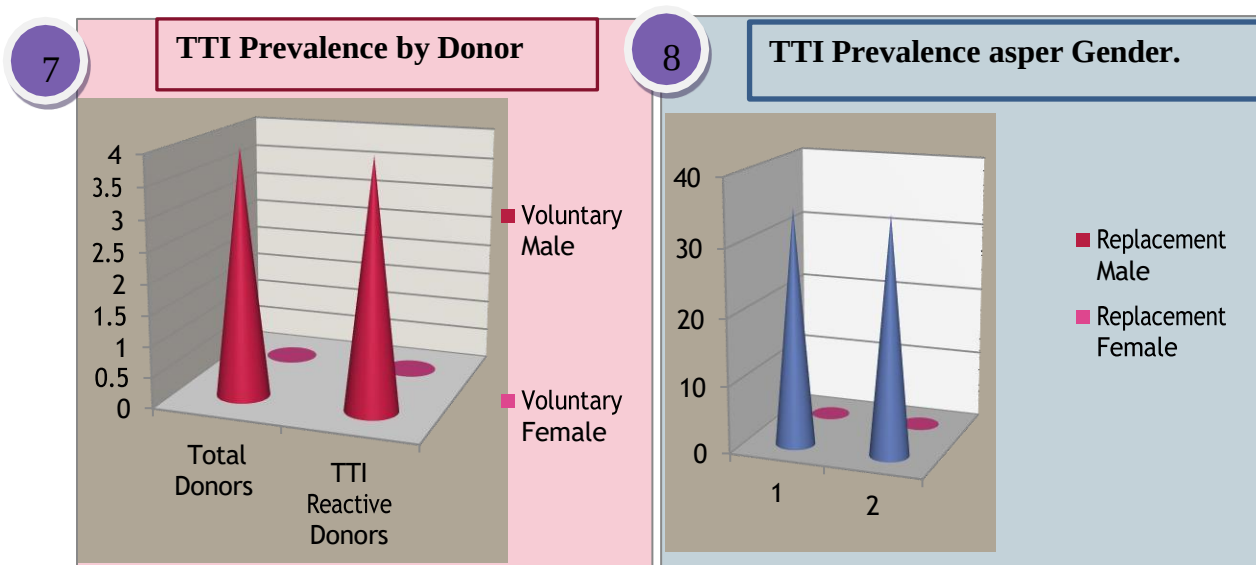


Figure 7,8: In the figure 8 Showing TTI Prevalence by Donor & 8 showing TTI Prevalence as per Gender. All reactive donors were male, and no female donors were founded.

Age Distribution and TTI Prevalence

Donors ranged in age from **18 to 61 years** (mean: 28.40 ± 8.53 years). The distribution across age categories was:

18–25 years: 38.1%

26–35 years: 34.2%

36–45 years: 17.4%

46–55 years: 8.5%

56–65 years: 1.8%

Chi-square testing demonstrated a **significant association** between **age group and TTI seropositivity** for:

HBV ($\chi^2 = 16.417$, $df = 4$, $p = 0.0025$)

HCV ($\chi^2 = 16.519$, $df = 4$, $p = 0.0024$)

HIV ($\chi^2 = 16.765$, $df = 4$, $p = 0.0021$)

However, the association between age and **syphilis** was **not statistically significant** ($\chi^2 = 7.110$, $p = 0.1302$).

The highest TTI positivity was observed among donors aged **26–35 years**, followed by those in the **36–45 years** group. This pattern is consistent with findings from other Indian and Asian studies, where sexually active and occupationally mobile age groups show higher exposure to blood-borne pathogens.

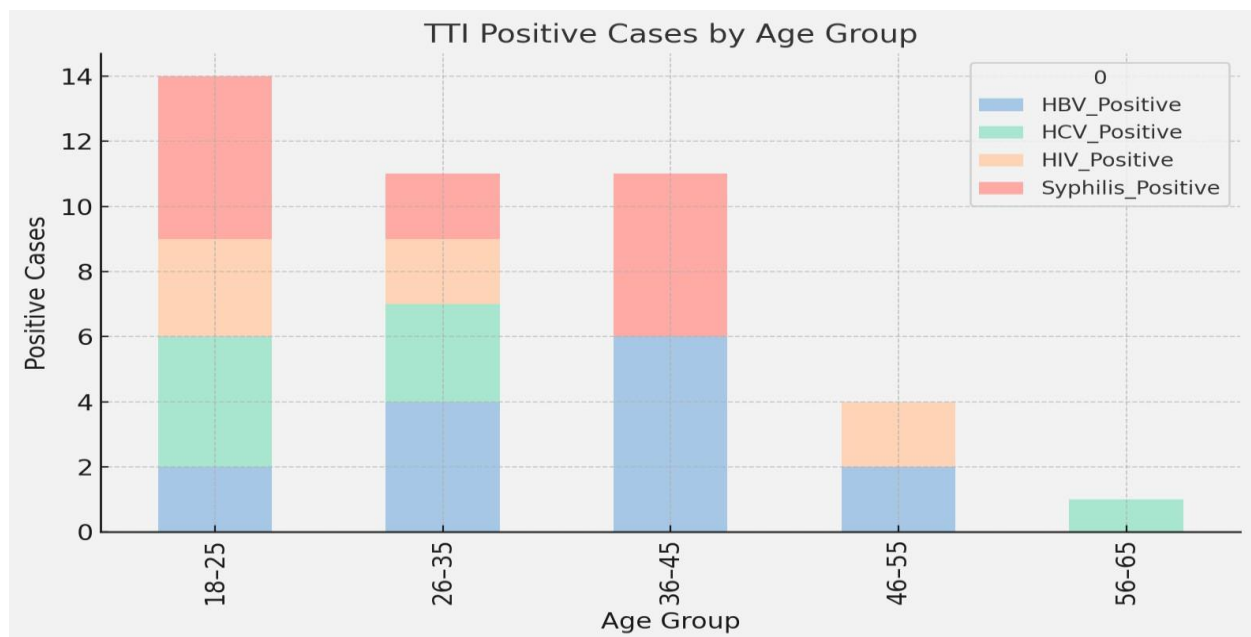


Figure 9: **Age-wise distribution of TTI-positive cases demonstrating significantly higher prevalence among donors aged 26–35 years, followed by the 36–45 years category.**

4. DISCUSSION

Ensuring the safety of blood transfusion services continues to be a major public health priority worldwide. The present study contributes to the ongoing surveillance of transfusion-transmissible infections (TTIs) among blood donors in Rajasthan. The overall TTI prevalence of 4.36% suggests that approximately one in every twenty-three donors may carry a potentially transmissible infection. Despite mandatory serological screening, the presence of silent infections indicates a residual risk in the blood supply.

Among individual pathogens, HBV exhibited the highest seroprevalence at 1.49%. This finding aligns with national trends, where HBV remains the leading transfusion-transmissible pathogen. India is a country with intermediate HBV endemicity, and horizontal transmission during adolescence or early adulthood remains common. The relatively high HBV positivity among donors emphasizes the need for stricter pre-donation screening and consideration of universal HBV vaccination among the general adult population.

Syphilis emerged as the second most prevalent TTI (1.28%). Though frequently overlooked, syphilis poses significant transfusion risks through early or latent stages when the infection may be asymptomatic. Its increasing prevalence may reflect unrecognized risky sexual behavior among younger donors, highlighting a need for improved sexual health awareness and counseling.

HCV and HIV seroprevalence in the present study was 0.85% and 0.74%, respectively, values comparable with other reports from India. The significant association of these TTIs with age, particularly the 26–35-year group, underscores behavioral and occupational exposure risks in the most sexually and economically active population. These findings advocate for targeted donor education focusing on safe practices and voluntary repeat donations from low-risk individuals.

Notably, all reactive cases were detected among male donors. This does not necessarily signify male exclusivity in infection transmission but rather highlights the gender disparity in donation practices across India, where female participation remains low due to sociocultural and health-related factors such as anemia prevalence. Increasing female donor engagement may diversify the donor pool while promoting inclusive blood safety strategies.

Replacement donors constituted the overwhelming majority of reactive cases. This is consistent with global evidence that voluntary non-remunerated repeat donors have significantly lower TTI prevalence. Replacement donors often donate under pressure for patient needs and may fail to disclose high-risk behaviors during donor interview. The present findings strongly support strengthening voluntary donor recruitment campaigns and reducing dependence on replacement donations.

Zero malaria positivity in the study suggests effective donor selection screening and better vector control programs in the region. However, malaria remains endemic in several Indian states, implying continuous alertness is necessary, especially during seasonal peaks.

Blood group–based analysis revealed higher TTI positivity among B Rh(D) positive donors, followed by O Rh(D) positive donors. While this partially reflects their distribution in the general population, previous research has hinted at immunogenetic susceptibility associations between certain blood groups and viral infections. However, such observations remain inconclusive and require larger multicenter genetic studies.

The presence of co-infections, although limited, further reinforces the importance of advanced sensitive diagnostic technologies. Serological methods, despite wide applicability, cannot fully eliminate window period transmission risks. Integration of nucleic acid amplification testing (NAT) could significantly reduce viral transmission by detecting early viremia; however, high costs remain a barrier for routine implementation in many centers.

Overall, this study highlights critical vulnerabilities in blood safety that require immediate mitigation strategies. Promoting regular repeat voluntary donations, enhancing health education, and improving national screening infrastructure remain crucial. Policy makers and transfusion services must work collaboratively toward minimizing the window period risk and addressing socio-behavioral determinants of infection among donor communities.

5. CONCLUSION

This study demonstrates that transfusion-transmissible infections continue to pose a silent but significant challenge to blood safety in Jaipur, Rajasthan. The overall seroprevalence of 4.36% among apparently healthy donors underscores the risk of disease transmission despite standard screening protocols. HBV remains the most common TTI, followed by syphilis, HCV, and HIV, while no malaria cases were identified. These findings are consistent with national epidemiological patterns.

Age was found to be a major predictor of TTI seropositivity, with donors aged 26–35 years representing the highest-risk group. This emphasizes the need for risk-based donor counseling focused on sexually active and occupationally mobile populations. Additionally, the predominance of positivity among replacement donors supports global recommendations prioritizing voluntary non-remunerated donors as the safest donor population.

Although the association between ABO/Rh blood groups and TTIs requires further investigation, the higher reactivity observed among B Rh-positive donors may offer future insights into host susceptibility factors.

The study further emphasizes the persistent limitations of serological assays in detecting early or occult infections. Wider implementation of NAT and confirmatory molecular testing could significantly reduce the residual risk of transfusion-associated transmission, particularly for HIV and hepatitis viruses.

To safeguard patients requiring transfusion therapy, it is essential to strengthen donor selection criteria, reinforce public awareness about safe donation practices, and encourage regular repeat voluntary donations. Continued regional surveillance of TTIs will help monitor evolving trends and guide appropriate health policy interventions.

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