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Research Article

Seroprevalence and Temporal Trends of Transfusion-Transmissible Infections among Blood Donors at a Tertiary Care Blood Centre in Eastern Uttar Pradesh

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ABSTRACT

Background: Blood transfusion is a critical, life-saving intervention in modern healthcare; however, it carries the inherent risk of transmitting infectious agents. Continuous epidemiological surveillance of blood donors is essential for ensuring the safety of the regional blood supply and evaluating the effectiveness of pre-donation screening protocols. **Objective:** This study aimed to determine the seroprevalence and analyze the temporal trends of major transfusion-transmissible infections (TTIs)—specifically Human Immunodeficiency Virus (HIV), Hepatitis B Virus (HBV), Hepatitis C Virus (HCV), Syphilis, and Malaria—among blood donors at a tertiary care teaching hospital in Eastern Uttar Pradesh, India, over a 4.5-year period. **Methods:** A retrospective observational study was conducted at the Blood Centre of Baba Kinaram Autonomous State Medical College, Chandauli, encompassing data from January 2022 to August 2026. Data on donor demographics, donation categories (voluntary versus replacement), and TTI reactivity were extracted from institutional registries. Screening was performed using Enzyme-Linked Immunosorbent Assays (ELISA) for HIV, HBV, and HCV, the Venereal Disease Research Laboratory (VDRL) test for Syphilis, and rapid antigen testing for Malaria. Statistical analysis utilized descriptive statistics and the Chi-square test. **Results:** A total of 17,357 blood donors were successfully screened. The cohort was overwhelmingly male (97.51%) and heavily reliant on replacement donors (87.59%). The overall seroprevalence of TTIs was 0.495% (n = 86). Hepatitis B was the predominant infection with a prevalence of 0.351%, followed by HCV (0.069%), HIV (0.046%), and Syphilis (0.012%). No cases of Malaria were detected. Multiple reactivities were found in 0.017% of donors. A statistically significant difference in TTI seroprevalence was observed between replacement donors (0.526%) and voluntary donors (0.278%) ($p = 0.032$). **Conclusion:** The overall prevalence of TTIs among blood donors in this region is relatively low, reflecting effective donor deferral strategies. However, the high burden of Hepatitis B and the profound reliance on replacement donors remain significant vulnerabilities. Robust public health campaigns are urgently required to promote 100% voluntary, non-remunerated blood donation and to encourage female participation, thereby reinforcing the safety and sustainability of the blood supply.

Keywords: Transfusion-Transmissible Infections, Blood Donors, Seroprevalence, Hepatitis B, Voluntary Donation, India

INTRODUCTION

Blood transfusion is an indispensable component of contemporary medical and surgical practice, playing a pivotal role in the management of severe trauma, major surgeries, obstetric hemorrhages, hematological malignancies, and chronic anemias. Despite its profound life-saving potential, blood transfusion inherently functions as a conduit for the transmission of infectious pathogens. Transfusion-transmissible infections (TTIs), which primarily encompass the

Human Immunodeficiency Virus (HIV), Hepatitis B Virus (HBV), Hepatitis C Virus (HCV), Syphilis (Treponema pallidum), and Malaria, represent a critical public health challenge and a severe threat to recipient safety [1]. The introduction of an infected unit of whole blood or its components into a vulnerable, often immunocompromised recipient can precipitate catastrophic health outcomes, including chronic liver disease, cirrhosis, hepatocellular carcinoma, acquired immunodeficiency syndrome (AIDS), and acute systemic multi-organ failure [2].

Globally, ensuring a safe and adequate blood supply remains a paramount priority for health organizations. The World Health Organization (WHO) unequivocally advocates for a transition to 100% voluntary, non-remunerated blood donation (VNRBD) and mandates rigorous, quality-assured screening of all donated blood to mitigate TTI risks [1]. In India, a rapidly developing nation characterized by immense population density and a high endemic burden of infectious diseases, maintaining absolute blood safety is a continuous and complex struggle [3]. The national prevalence of TTIs in the general Indian populace creates a substantial pool of asymptomatic carriers who may present at blood centers as prospective donors, unaware of their infectious status.

To combat this, the National AIDS Control Organization (NACO) and the National Blood Transfusion Council (NBTC) of India have established stringent guidelines dictating the universal screening of all donated blood units for five mandatory infectious markers [4]. Furthermore, national health policies heavily emphasize the need to shift away from family or replacement donations toward purely voluntary pools. However, this transition is far from complete. The Indian blood donor pool is still primarily bipartite, comprising voluntary donors driven by altruism, and replacement donors who are compelled to donate to replace the blood utilized by their relatives or acquaintances [5]. Replacement donors are inherently more prone to concealing high-risk behaviors or underlying health issues to ensure their loved ones receive necessary medical treatment, rendering them a statistically riskier cohort for harboring infectious agents [5].

Uttar Pradesh, as the most populous state in India, presents unique socio-demographic, cultural, and healthcare challenges. The eastern region of the state, in particular, serves a vast, largely rural, and semi-urban population with disparate levels of health literacy and varying access to primary healthcare infrastructure. Previous regional epidemiological studies conducted across different states in India have reported highly heterogeneous TTI prevalence rates, often dictated by local endemicity and the prevailing culture of blood donation [6]. While some heavily urbanized centers with robust voluntary networks report minimal infectious markers, centers reliant on replacement donations in rural settings often document concerning levels of seropositivity [7-8]. Specifically, Hepatitis B continues to dominate the TTI landscape throughout the Indian subcontinent, posing a persistent threat despite the availability and integration of an effective vaccine into national immunization programs.

Despite these established national trends, there remains a distinct paucity of recent, long-term, and localized epidemiological data concerning the precise seroprevalence and temporal trends of TTIs in Eastern Uttar Pradesh, particularly in newly established tertiary care institutions that cater directly to marginalized and semi-urban communities. Addressing this critical research gap is imperative for evaluating the local efficacy of current pre-donation counseling and screening protocols, understanding the evolving epidemiology of viral and parasitic markers, and formulating targeted local interventions to augment blood safety.

Therefore, the present study was undertaken with the primary aim of thoroughly assessing the seroprevalence and mapping the temporal trends of HIV, HBV, HCV, Syphilis, and Malaria among blood donors at a tertiary care blood centre in Eastern Uttar Pradesh over a continuous 4.5-year period. A secondary objective was to comparatively analyze the burden of these infections between voluntary and replacement donor categories to provide actionable insights for regional health policymakers.

MATERIALS AND METHODS

Study Design and Setting

A retrospective observational study was meticulously designed to evaluate the seroprevalence and temporal trends of transfusion-transmissible infections (TTIs) among blood donors. The study was conducted at the Blood Centre of Baba Kinaram Autonomous State Medical College, a prominent tertiary care teaching hospital situated in Chandauli, Eastern Uttar Pradesh, India. This institution serves as a critical healthcare hub for a diverse and densely populated demographic encompassing surrounding rural, tribal, and semi-urban districts.

Study Duration and Population

The study covered a continuous, multi-year period of exactly 4 years and 8 months, extending from January 2022 to August 2026. The comprehensive study population comprised all eligible prospective blood donors who successfully underwent the donation process at the institutional blood center or during various outreach blood donation camps organized by the medical college within the specified timeframe. Both voluntary, non-remunerated donors and family/replacement donors were systematically included in the study cohort.

Inclusion and Exclusion Criteria

Stringent inclusion criteria were applied to ensure data integrity. The study included all voluntary blood donors and all replacement blood donors whose blood samples were successfully drawn, processed, and subjected to complete screening for all five mandatory mandatory transfusion-transmissible infections. Only donations possessing complete, verifiable, and unambiguous TTI screening and demographic records within the institutional database were deemed eligible for final analysis.

Conversely, the exclusion criteria involved the rigorous rejection of any records that were incomplete or where TTI screening results for any of the five markers were unavailable. Furthermore, records exhibiting missing, illegible, or inconsistent essential demographic variables (such as gender or donor category) were excluded. Any duplicate entries, erroneous documentation, or data corresponding to donors who were deferred during the pre-donation medical examination and did not proceed to phlebotomy were strictly excluded from the final dataset.

Data Collection Procedure

An exhaustive, systematic review of the official blood bank laboratory records, donor questionnaires, and digital registries was executed to retrieve the necessary epidemiological and serological data. The data were extracted month-wise and year-wise. The primary variables extracted for subsequent analysis included the total volume of successful donations, precise donor categorization (stratified into voluntary donations—including both in-house walk-ins and outreach camps—versus replacement donations), the gender distribution of the donor pool, and the absolute numbers of reactive units for HIV, HBV, HCV, Syphilis (VDRL), Malaria, and instances of multiple pathogen reactivity.

Laboratory Methods and Instruments

Adhering to the stringent mandates of the Drugs and Cosmetics Act of India and NACO guidelines, all collected whole blood units were universally and compulsorily screened for the five major TTIs. The screening processes were executed using state-of-the-art diagnostic kits, highly calibrated equipment, and standard operating procedures.

The virological screening for HIV-1 and HIV-2, Hepatitis B surface antigen (HBsAg), and anti-HCV antibodies was performed employing highly sensitive and specific Enzyme-Linked Immunosorbent Assays (ELISA). Specifically, diagnostic kits manufactured by J. Mitra & Co. Pvt. Ltd. were consistently utilized throughout the study period to maintain methodological uniformity. Serological testing for Syphilis was conducted using the standard Venereal Disease Research Laboratory (VDRL) test via the slide flocculation method. Parasitological screening for Malaria was executed via rapid antigen detection methodologies utilizing the J. Mitra malaria rapid diagnostic kit.

The primary laboratory instruments utilized during the analytical phase included automated microplate ELISA readers, ELISA microplate washers, precision micropipettes, standard VDRL rotators, laboratory centrifuges for proper serum separation, and regulated medical-grade refrigerators meticulously maintaining a strict temperature range of 2–8°C for the preservation of reagents and serum samples. Standard protocol dictated that all samples demonstrating initial reactivity on the primary screening were subsequently subjected to duplicate repeat testing utilizing the same assay methodologies. A blood unit was definitively declared reactive and subsequently discarded according to biohazard protocols only if it demonstrated consistent reactivity upon repeat testing.

Statistical Analysis

The raw extracted data were thoroughly cleaned, validated, and entered into a centralized Microsoft Excel spreadsheet. Subsequent statistical evaluation was performed using the Statistical Package for the Social Sciences (SPSS) software, version 25.0. Descriptive statistical methods were extensively employed to calculate absolute frequencies, proportional percentages, and specific seroprevalence rates. Seroprevalence was mathematically defined as the number of confirmed reactive donations divided by the total number of screened donations, expressed as a percentage. To determine the statistical significance of differences in TTI prevalence between the independent categorical variables (specifically, voluntary versus replacement donors), the Pearson Chi-square ($\chi 2$) test was utilized. A two-tailed p-value of less than 0.05 was established as the threshold for statistical significance.

RESULTS

Over the exhaustive 4.5-year study period spanning from January 2022 to August 2026, a cumulative total of 17,357 blood donations was successfully collected, processed, and serologically screened at the tertiary care blood center.

Demographic and Donation Characteristics

The demographic profiling of the donor cohort, as detailed comprehensively in Table 1, revealed a profound and persistent gender disparity. The donor pool was overwhelmingly dominated by male participants, who accounted for

Table 1: Demographic and Donation Characteristics of Blood Donors (2022–2026)

Year	Total Donors	Voluntary Donors n (%)	Replacement Donors n (%)	Male Donors n (%)	Female Donors n (%)
2022	3,055	486 (15.91)	2,569 (84.09)	2,960 (96.89)	95 (3.11)
2023	3,080	520 (16.88)	2,560 (83.12)	2,961 (96.14)	119 (3.86)
2024	3,104	352 (11.34)	2,752 (88.66)	3,022 (97.36)	82 (2.64)
2025	4,581	445 (9.71)	4,136 (90.29)	4,494 (98.10)	87 (1.90)
2026*	3,537	351 (9.92)	3,186 (90.08)	3,488 (98.61)	49 (1.39)
Total	17,357	2,154 (12.41)	15,203 (87.59)	16,925 (97.51)	432 (2.49)

Table 2: Year-wise Seroprevalence of Transfusion-Transmissible Infections

Year	Total Donors	HIV n (%)	HBV n (%)	HCV n (%)	VDRL n (%)	Malaria n (%)	MR* n (%)	Total TTIs n (%)
2022	3,055	3 (0.098)	15 (0.491)	2 (0.065)	2 (0.065)	0 (0.00)	0 (0.00)	22 (0.720)
2023	3,080	0 (0.00)	10 (0.325)	1 (0.032)	0 (0.00)	0 (0.00)	0 (0.00)	11 (0.357)
2024	3,104	1 (0.032)	14 (0.451)	2 (0.064)	0 (0.00)	0 (0.00)	3 (0.097)	20 (0.644)
2025	4,581	1 (0.022)	13 (0.284)	1 (0.022)	0 (0.00)	0 (0.00)	0 (0.00)	15 (0.327)
2026	3,537	3 (0.085)	9 (0.254)	6 (0.170)	0 (0.00)	0 (0.00)	0 (0.00)	18 (0.509)
Total	17,357	8 (0.046)	61 (0.351)	12 (0.069)	2 (0.012)	0 (0.00)	3 (0.017)	86 (0.495)

Table 3: Comparison of TTIs between Voluntary and Replacement Donors (2022–2026)

Infection Marker	Voluntary Donors (N = 2,154)	Replacement Donors (N = 15,203)	Total Cases (N = 17,357)
HIV	0 (0.00%)	8 (0.052%)	8
HBV	5 (0.232%)	56 (0.368%)	61
HCV	1 (0.046%)	11 (0.072%)	12
VDRL	0 (0.00%)	2 (0.013%)	2
Malaria	0 (0.00%)	0 (0.00%)	0
Multiple Reactive	0 (0.00%)	3 (0.019%)	3
Total TTIs	6 (0.278%)	80 (0.526%)	86

Statistical significance of total TTIs between groups: p = 0.032

16,925 (97.51%) of the total donations. In stark contrast, female donors constituted a mere fraction of the cohort, contributing only 432 (2.49%) donations across the entire period.

The analysis of donation motivations and categories highlighted a heavy, systemic reliance on replacement donation frameworks. Out of the 17,357 total donations, an overwhelming majority of 15,203 (87.59%) were classified as replacement donations. Voluntary donations (encompassing both in-house individuals and outreach camp participants) accounted for only 2,154 (12.41%) of the overall supply. A temporal, year-over-year analysis of these donation trends indicated a peak in the proportional participation of voluntary donors during the year 2023 at 16.88%. However, this was followed by a concerning and steady decline, plunging to 11.34% in 2024, 9.71% in 2025, and stagnating at 9.92% by the first eight months of 2026. Correspondingly, female donor participation experienced a similar trajectory; peaking in 2023 at 3.86%, but steadily deteriorating to a critical low of just 1.39% by 2026.

Year-wise Seroprevalence of Transfusion-Transmissible Infections

The rigorous serological screening of the 17,357 units identified a total of 86 units that were reactive for at least one mandatory TTI, culminating in an overall seroprevalence rate of 0.495%. The distinct distribution and temporal trends of the individual infectious markers are systematically presented in Table 2.

Hepatitis B virus (HBV) was unequivocally identified as the most frequent and dominant infection within the regional donor population. HBV accounted for 61 of the total positive cases, yielding an individual seroprevalence of 0.351%. This was distantly followed by Hepatitis C Virus (HCV) with 12 positive cases (0.069%), and the Human Immunodeficiency Virus (HIV) with 8 confirmed cases (0.046%). Syphilis (VDRL) reactivity was observed to be exceedingly low, detected in only 2 cases (0.012%), with both isolated cases occurring exclusively during the year 2022.

Most notably, zero donors tested positive for the Malaria parasite throughout the entirety of the 4.5-year evaluation, resulting in a 0.00% prevalence. Instances of multiple co-infections (donors testing reactive for more than one TTI simultaneously) were rare, observed in only 3 individuals (0.017%). A nuanced temporal analysis revealed minor fluctuations in the overarching TTI burden, which peaked initially at 0.720% in 2022, demonstrated a substantial drop to 0.327% in 2025, before exhibiting a slight upward correction to 0.509% in the abbreviated 2026 timeframe.

Comparison of TTIs between Voluntary and Replacement Donors

Table 3 delineates a critical comparative analysis of TTI seroprevalence fundamentally based on the motivational category of blood donation. Among the massive cohort of 15,203 replacement donors, exactly 80 individuals tested

positive for one or more TTIs, translating to a categorical seroprevalence of 0.526%. Conversely, within the much smaller pool of 2,154 voluntary donors, merely 6 infections were identified, resulting in a substantially lower categorical seroprevalence of 0.278%.

The statistical evaluation utilizing the Pearson Chi-square test revealed that the elevated rate of infectious markers among replacement donors compared to voluntary donors was statistically significant ($p = 0.032$). While HBV constituted the vast majority of all infections in both discrete groups, it is imperative to note that all instances of HIV and Syphilis infections were exclusively isolated from the replacement donor pool, with voluntary donors exhibiting zero reactivity for these specific pathogens.

DISCUSSION

The provision of a secure, sustainable, and reliable blood supply necessitates continuous, granular epidemiological surveillance of the donor population. Such surveillance is paramount not only for assessing the real-world efficacy of pre-donation counseling and laboratory screening but also for identifying prevalent infectious threats circulating within the asymptomatic general community. This comprehensive 4.5-year retrospective analysis details the seroprevalence and shifting trends of major transfusion-transmissible infections at a tertiary healthcare center in Eastern Uttar Pradesh, thereby reflecting the broader, systemic challenges routinely encountered by blood transfusion services in densely populated, developing geopolitical regions.

The overall cumulative seroprevalence of TTIs in our study cohort was remarkably low at 0.495%. This overarching reactivity rate demonstrates a highly favorable and encouraging epidemiological profile when benchmarked against numerous prior studies conducted both across the diverse landscapes of the Indian subcontinent and internationally. For instance, a prominent study by Arora et al. in Northern India documented an overall TTI prevalence of 1.35%, substantially higher than our findings [9]. Similarly, Pallavi et al., investigating donor populations in South India, reported a cumulative positivity rate approaching 1.5% [10]. In a broader international context, long-term evaluations in Sub-Saharan Africa, such as those conducted by Okoroiwu et al. in Nigeria, regularly report baseline reactivities exceeding 14%, indicative of severe endemic burdens in those regions [11]. The relatively low overall rate observed in the present study (0.495%) can likely be attributed to the implementation of increasingly rigorous and strict donor deferral protocols, highly effective pre-donation counseling that successfully weeds out high-risk individuals prior to phlebotomy, and a hypothesized enhancement in overarching public health awareness in the post-pandemic era.

When disintegrating the overall burden into individual infectious etiologies, the Hepatitis B virus (HBV) unequivocally emerged as the leading TTI, accounting for 61 of the 86 total positive cases and exhibiting an isolated prevalence of 0.351%. The dominance of HBV within the ostensibly healthy donor population is a persistent, alarming trend widely acknowledged and extensively documented in Indian medical literature. Pahuja et al. comprehensively mapped viral trends in Indian blood banks and confirmed that HBV continually outpaces all other viral markers, a consequence of deep-seated endemicity [12]. The sustained burden of HBV reflects the significant asymptomatic carrier pool thriving in the general population. This vast reservoir primarily stems from pervasive horizontal transmission occurring in early childhood, compounded by maternal vertical transmission, and is further exacerbated by the sub-optimal historical penetration of the universal Hepatitis B vaccination program into deeper rural and marginalized socioeconomic pockets.

Conversely, the recorded seroprevalence rates for HCV (0.069%) and HIV (0.046%) were reassuringly low in our cohort. These findings align with observations by Makroo et al., who noted a gradual, stabilizing decline in HCV reactivity among North Indian blood donors due to improved socio-medical awareness [13]. Furthermore, Alqahtani et al. in Saudi Arabia similarly identified HCV and HIV as markedly less frequent than HBV among thoroughly screened donor pools, reflecting the distinctly different transmission dynamics and epidemiological determinants of these viruses [14].

A highly striking and significant finding in the present study was the absolute, verified absence of Malaria reactivity (0.00%) across all 17,357 screened units over the comprehensive 4.5-year span. Malaria is conventionally categorized as highly endemic to various parts of India, including the Gangetic plains; however, its documented seropositivity among asymptomatic blood donors has historically proven to be highly variable. Chattopadhyay et al. noted that malarial positivity in blood banks fluctuates wildly depending on seasonal monsoonal outbreaks and the precise micro-geographical location of the center [15]. The zero prevalence unequivocally noted in our data strongly suggests the successful execution of district-level vector control programs in Chandauli, coupled with the meticulous, stringent exclusion of any donors presenting with a recent history of febrile illness during the clinical examination phase. Additionally, syphilis (VDRL) reactivity was extremely rare (0.012%) and entirely confined to the initial year of the study (2022).

Despite the profoundly encouraging low overall TTI burden, our dataset glaringly exposes deep, systemic operational disparities concerning donor demographics. The participant pool was severely skewed both socially and biologically, with male donors comprising an overwhelming 97.51% of the entire cohort. Female donor participation

languished at a dismal average of 2.49%, dipping to an unprecedented low of 1.39% in 2026. This stark gender disparity is a widely recognized, chronic phenomenon in Indian transfusion medicine. As extensively detailed by Kaur et al., this failure is primarily driven by alarmingly high baseline rates of nutritional anemia among women of childbearing age (leading to immediate hemoglobin-based deferrals), interwoven with deep-rooted socio-cultural stigmas, misconceptions regarding physical weakness post-donation, and a severe lack of targeted, female-centric motivational campaigns by health authorities [16]. Addressing this catastrophic female underrepresentation represents a vast, wholly untapped potential for safely expanding the regional blood pool.

Furthermore, the very foundation of the blood supply in this tertiary center rests precariously upon replacement donors, who accounted for an astounding 87.59% of all donations. While global health authorities advocate relentlessly for the complete abolition of replacement donation systems to minimize the residual risk of the immunological window period, our institution recorded a highly concerning downward trajectory in voluntary donation, collapsing from 16.88% in 2023 to under 10% in 2026. Crucially, our statistical analysis confirms that the seroprevalence of TTIs was significantly and definitively higher among replacement donors (0.526%) compared to voluntary donors (0.278%) ($p = 0.032$). This significant divergence reinforces the established paradigm that replacement donors, operating under intense familial or societal pressures, are psychologically compelled to bypass vital self-deferral criteria despite potentially harboring high-risk lifestyle exposures. Tigabu et al., in a comprehensive analysis in Ethiopia, similarly emphasized that the reliance on non-voluntary familial donors systematically and dangerously inflates the infectious burden of the local blood bank ecosystem [17]. The immediate imperative for regional blood centers is to actively reverse this trend through aggressive community outreach, the deployment of mobile collection units, and continuous, culturally resonant educational interventions.

CONCLUSIONS

The ultimate safety and viability of the modern blood supply remain intrinsically tethered to the overarching epidemiological health and altruistic nature of the donor pool. This extensive study successfully established a highly favorable, low overall TTI seroprevalence (0.495%) among blood donors at a tertiary care center in Eastern Uttar Pradesh, actively showcasing the effectiveness of current clinical screening and deferral protocols. However, the absolute dominance of Hepatitis B continues to highlight an ongoing, deeply entrenched regional public health challenge. Most critically, the overwhelming, systemic dependency on replacement donors—who demonstrated a statistically significant, higher risk of carrying dangerous infectious markers compared to their voluntary counterparts—represents a critical structural vulnerability. To definitively fortify blood safety and ensure long-term, sustainable sufficiency, aggressive, coordinated governmental and institutional initiatives must be mobilized immediately to cultivate a culture of 100% voluntary, non-remunerated blood donation, while concurrently deploying targeted strategies to dismantle the sociomedical barriers that severely restrict female participation.

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