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TRANSFUSION-TRANSMITTED INFECTIONS AMONG BLOOD DONORS: A REVIEW OF EPIDEMIOLOGICAL TRENDS AND SCREENING STRATEGIES

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ABSTRACT

Transfusion-transmitted infections (TTIs) — chiefly hepatitis B virus (HBV), hepatitis C virus (HCV), human immunodeficiency virus (HIV), and syphilis — remain a global blood-safety concern despite decades of improvement in donor screening. This review synthesises the epidemiological and screening-technology literature underlying a retrospective cross-sectional thesis study of 6,346 blood donors at a tertiary-care hospital blood bank in Sirsa, Haryana (October 2024 to June 2026), which recorded an overall TTI seroreactivity of 3.29%, with syphilis (VDRL, 2.68%) and HCV (2.26%) as the leading markers. The review traces the historical evolution of transfusion safety from the discovery of the ABO system and Rh factor through the adoption of ELISA and, more recently, Nucleic Acid Testing (NAT); summarises global and Indian epidemiological data showing marked regional heterogeneity in HBV, HCV, and HIV prevalence among donors; and compares findings across twelve published donor-screening studies from India and neighbouring countries. Across studies, male donors consistently predominate (>90%), and prevalence differences are attributable to donor-selection practices, the proportion of voluntary versus replacement donors, regional disease burden, and screening-assay sensitivity. The review concludes that while HIV and HBV transmission risk has fallen substantially with serological screening, HCV and syphilis remain comparatively persistent concerns, and that wider adoption of NAT, expansion of the Haemovigilance Programme of India, and promotion of 100%

voluntary non-remunerated donation are the priority measures for further reducing residual transfusion risk.

KEYWORDS: Transfusion-transmitted infections; blood donors; HBV; HCV; HIV; syphilis; ELISA; Nucleic Acid Testing; haemovigilance.

1. INTRODUCTION

Safe and adequate blood transfusion is a cornerstone of modern healthcare, supporting the management of trauma, obstetric haemorrhage, major surgery, haematological disorders, and chronic transfusion-dependent conditions such as thalassaemia. The World Health Organization (WHO) estimates approximately 112 million blood donations are collected globally each year, over half from high-income countries that represent only 19% of the world's population (World Health Organization, 2022; WHO, 2017), leaving many low- and middle-income regions with persistent shortages and, in Africa specifically, a gap of roughly 5 million units between estimated need and supply (Tapko et al., 2006; Bloch et al., 2012).

Alongside availability, transfusion safety is a continuing challenge because donated blood can transmit infectious agents — principally HBV, HCV, and HIV, together with syphilis and, in endemic regions, malaria. Global disease-burden estimates put approximately 71.0 million people living with HCV, 257 million with HBV, and 36.7 million with HIV, with millions more affected by HCV/HIV or HBV/HIV co-infection through shared transmission routes (Joshi et al., 2025). This review consolidates the historical, epidemiological, and screening-technology literature relevant to transfusion-transmitted infections, using as its empirical anchor a retrospective thesis study of TTI seroprevalence among blood donors at a tertiary-care hospital blood bank, and situates that study's findings within the wider published evidence from India and comparable settings.

2. Historical Evolution of Transfusion Safety and Donor Screening

Blood transfusion practice dates to unsuccessful 17th-century attempts at transfusing animal blood into humans (López-Plaza et al., 2019). Transfusion medicine was transformed by Karl Landsteiner's 1901 discovery of the ABO blood group system, which enabled compatible donor-recipient matching (Landsteiner, 1901), followed by the 1940 characterisation of the Rh factor, which further reduced haemolytic transfusion risk (Levine and Stetson, 1940). Advances in anticoagulant solutions and refrigerated storage during the mid-20th century, accelerated by wartime demand, enabled organised blood banking and large-scale supply systems (Mollison, 2000).

The emergence of HBV, HCV, and HIV as recognised transfusion risks in the late twentieth century shifted attention toward donor screening. Enzyme-linked immunosorbent assay (ELISA) became the mainstay screening method, detecting antigens or antibodies but leaving a diagnostic 'window period' between infection and a measurable immune response (Busch et al., 2000). Nucleic Acid Testing (NAT), introduced in Germany in 1997 and adopted more widely through the early 2000s, detects viral RNA/DNA directly and substantially shortens this window — by an estimated 15 days for HBV, 4 days for HCV, and 6 days for HIV (Hourfar et al., 2008; Naidu et al., 2016). NAT is now universal in the United States, but in India it remains confined to selected centres and is not yet mandated under the Drugs and Cosmetics Act, 1940 (Hans et al., 2014).

3. Global and Indian Epidemiology of Transfusion-Transmitted Infections

TTI epidemiology varies considerably by region, reflecting donor demographics, background disease prevalence, screening-assay sensitivity, and the proportion of voluntary versus replacement donors. High-income countries using NAT-supplemented screening report very low residual TTI risk, whereas countries such as South Africa, Thailand, and Ghana continue to report comparatively higher donor seroprevalence linked to serology-only screening and limited infrastructure (Jain et al., 2012). WHO estimates the per-unit residual transmission risk in well-regulated systems at roughly 1 in 200,000–360,000 for HBV, 1 in 1–2 million for HCV, and 1 in 1.5–2 million for HIV (Kleinman, 2018).

Within India, reported HBV prevalence among donors ranges as high as 1–12%, with substantial inter-regional variation: North India 0.15% (Kaur et al., 2015), Punjab 0.13% (Kabita et al., 2016), Rajasthan 0.034% transmission risk (Kaur et al., 2014), and Central India 2.2% HBV / 0.3% HCV in pilot data (Punde et al., 2011; Bhargava et al., 2014). Comparable South Asian data show Pakistan with markedly higher combined prevalence (HBsAg 2.68%, HCV 2.46%, HIV 0.06%, syphilis 0.43% across 127,828 donors; Alam et al., 2014) contrasted with very low prevalence in Bangladesh (Shrestha et al., 2009) and low-to-moderate rates in Nepal. This heterogeneity underscores that rural and resource-limited settings, which rely more heavily on replacement donors and rapid serological kits, generally carry higher residual TTI risk than urban centres with established voluntary-donation programmes and NAT access.

4. Comparative Evidence from Donor-Screening Studies

Table 1 summarises TTI seroprevalence reported across twelve published donor-screening studies, alongside the reviewed thesis study, illustrating both the consistency of low HIV prevalence following widespread serological screening and the comparatively greater variability seen for HBV, HCV, and syphilis.

Table 1. Comparative TTI seroprevalence across published donor-screening studies (— = not reported separately; * combined syphilis+other; ** approximate, derived from case counts).

Study	Year	Sample Size	HBV (%)	HCV (%)	HIV (%)	VDRL (%)	Overall TTI (%)
Arora et al.	2010	20,803	0.95	0.54	0.21	0.41	2.11
Makroo et al.	2015	180,371	0.91	0.34	0.16	0.23	2.98
Patel et al.	2017	32,845	0.82	0.51	0.19	0.28	3.10
Chandra et al.	2019	75,000	1.50	0.42	0.18	0.32	2.53
Zubair Mohd et al.	2020	31,733	0.22	0.16	0.009	0.01*	0.40
Adhikary et al.	2021	43,775	0.28	0.12	—	—	0.42
Kolur A.	2022	3,183	0.44**	—	—	0.06**	0.53
Shaila et al.	2023	22,760	—	—	—	—	—
H.A. Dahie et al.	2024	36,296	—	—	—	—	2.99
Joshi et al.	2025	3,405	0.73	0.15	0.12	2.06	3.05
Farah et al.	2025	19,021	1.20	0.10	0.10	0.30	1.60
Present study (reviewed thesis)	2026	6,346	0.88	2.26	0.05	2.68	3.29

Across these studies, replacement donors consistently show higher TTI reactivity than voluntary donors — for example, Zubair Mohd et al. (2020) reported infection rates roughly threefold higher among replacement (77% of their donor pool) than voluntary donors, and Shaila et al. (2023) similarly found higher HIV, HBV, HCV, and VDRL positivity among replacement donors across 22,760 donations. Male donors constitute the overwhelming majority in every study reviewed (generally 90–99.8%), and the 18–40-year age band consistently accounts for the largest share of donations, reflecting greater awareness and eligibility among young and middle-aged adults.

5. DISCUSSION: Determinants of TTI Prevalence and Blood-Safety Strategy

The comparative evidence indicates that HIV seroprevalence among Indian blood donors has fallen to consistently low levels (generally well under 0.2%), attributable to the combined effect of universal HIV antibody screening, National AIDS Control Programme activities, and pre-donation counselling. HBV prevalence, while historically higher, shows a similar

downward trajectory across more recent studies compared with older reports exceeding 1.5%, plausibly reflecting expanding hepatitis B immunisation coverage and improved donor deferral criteria.

HCV and syphilis (VDRL) present a less uniform picture. Several recent studies, including the reviewed thesis, report HCV and VDRL prevalence at or above 2%, exceeding the levels reported in earlier multicentre Indian studies (Makroo et al., 2015; Chandra et al., 2019; Patel et al., 2017). Because Treponema pallidum survives poorly in stored blood, syphilis screening functions less as a direct transfusion-transmission safeguard and more as a proxy marker of high-risk sexual behaviour in the donor pool — meaning elevated VDRL reactivity should prompt broader risk-behaviour screening and counselling rather than being interpreted solely as a transfusion hazard. Multiple-marker (co-infection) reactivity remains rare across all reviewed studies (typically well under 0.1% of donors) but carries disproportionate clinical significance, since co-infected donors and any inadvertently released units warrant close follow-up.

Two structural factors recur across the literature as key levers for further reducing residual TTI risk. First, the proportion of voluntary, non-remunerated donors versus replacement/family donors is repeatedly associated with lower TTI prevalence, reinforcing WHO's long-standing emphasis on voluntary donation as the safest and most sustainable basis for a national blood supply (WHO, 2011). Second, the sensitivity gap between ELISA and NAT — particularly during the diagnostic window period — remains the principal source of residual transfusion risk in serology-only settings; broader NAT adoption, although constrained in India by cost and infrastructure, is consistently identified as the single most impactful technical intervention available. The Haemovigilance Programme of India provides a complementary, system-level safeguard by tracking adverse transfusion events, but its impact is currently limited by incomplete blood-bank enrolment (Bisht et al., 2018; Mukherjee et al., 2016).

6. CONCLUSION AND RECOMMENDATIONS

The literature reviewed here, read alongside the findings of the reviewed thesis study (overall TTI seroreactivity 3.29% among 6,346 donors, led by VDRL and HCV), confirms that transfusion-transmitted infections continue to circulate among apparently healthy blood donors even where serological screening is well established. HIV and, increasingly, HBV transmission risk have been substantially curtailed by current screening and donor-selection

practices, but HCV and syphilis remain comparatively persistent concerns warranting targeted attention.

Based on the combined evidence, priority measures include: (1) promoting 100% voluntary, non-remunerated donation to improve donor-pool safety; (2) strengthening pre-donation counselling to identify and defer high-risk donors; (3) expanding hepatitis B immunisation coverage and public awareness; (4) intensifying screening and awareness efforts specifically for HCV and sexually transmitted infections; (5) extending Nucleic Acid Testing wherever feasible to close the residual window-period gap; (6) reinforcing the Haemovigilance Programme of India through wider enrolment and consistent reporting; and (7) conducting further multicentre, prospective studies to characterise regional variation in TTI prevalence and inform region-specific blood-safety policy.

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