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Transfusion-Transmitted Infections (TTIs)

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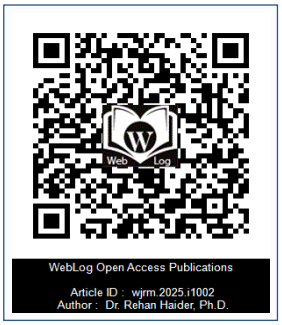

Abstract

Blood transfusions are essential and life-saving procedures, particularly in surgical, trauma, oncology, and hematology settings. However, transfusion-transmitted infections (TTIs) remain a major concern for transfusion safety, especially in resource-limited regions. TTIs involve the transmission of pathogens such as viruses, bacteria, parasites, and prions through contaminated blood or blood components. The most concerning TTIs include human immunodeficiency virus (HIV), hepatitis B virus (HBV), hepatitis C virus (HCV), syphilis, and malaria. Despite advancements in donor screening and nucleic acid testing (NAT) methods, challenges persist due to the window period of infections, asymptomatic carriers, and emerging pathogens. The prevalence of TTIs is influenced by the epidemiological patterns of infectious diseases in donor populations, the effectiveness of donor selection procedures, and the quality of testing methods used.

This paper highlights the most common pathogens associated with TTIs and current prevention strategies, including donor deferral protocols, advancements in pathogen detection technologies, and the importance of hemovigilance systems. It also discusses global disparities in blood safety, emphasizing the need for investment in infrastructure, training, and regulatory oversight to improve transfusion practices. Furthermore, it underscores the significance of public awareness and voluntary, non-remunerated blood donation as essential components of a safe blood supply. Achieving transfusion safety requires an integrated approach that combines clinical vigilance, laboratory accuracy, and effective public health policies. Reducing the burden of TTIs is crucial to maintaining public trust in blood services and improving patient outcomes

Keywords: Transfusion-Transmitted Infections, Blood Safety, HIV, Hepatitis B, Hepatitis C, Donor Screening, Pathogen Detection, Hemovigilance

Introduction

Blood transfusions are critical in conditional lives and improving well-being effects in various medical fields, in the way as medical procedure, pain care, obstetrics, and hematology [1]. While these transfusions offer significant benefits, they again bear hereditary risks. One of the most meaningful risks is the broadcast of infections from patron to receiver, usually known as transference-communicated contaminations (TTIs) [2, 3]. These infections may be precipitated by a range of pathogens, including viruses, bacteria, dependents, and prions, and show a solid global challenge to guaranteeing ancestry security [4].

Among the most accepted pathogens that guide TTIs are human immunodeficiency virus (HIV), hepatitis B virus (HBV), hepatitis C virus (HCV), diseases transmitted through sexual relations, and malaria [5-7]. The risk of broadcast is particularly extreme in lower- and middle-earnings nations, where hide codes and the infrastructure for ancestry security are frequently insufficient [8, 9]. Although modern demonstrative methods, to a degree, nucleic acid testing (NAT), have considerably lowered the risk by shortening the fenestella ending to discovery, many regions still lack access to these technologies [10, 11].

The main defenses against TTIs are benefactor hide and pre-donation energy codes. Evidence shows that willing, unpaid ancestry gifts are associated with a lower prevalence of TTIs compared to compensated or family-substitute gifts [12, 13]. However, in spite of rigorous hide, TTIs can still happen on account of the presence of asymptomatic aircraft carriers, the challenges of detecting contaminations all the while the window is ending, and the rise of new pathogens that are not now covered by existing tests [14-17].

Effective hemovigilance methods and tight regulation of ancestry produce knowledge in blood banks play an essential role in the early discovery and prevention of transfusion-accompanying

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Table 1: Residual Risk of TTIs per Blood Unit in Selected Countries.

Country	HIV Risk (per unit)	HBV Risk (per unit)	HCV Risk (per unit)	Screening Method
USA	1 in 1.9 million	1 in 280,000	1 in 1.6 million	NAT + Serology
UK	1 in 4.3 million	1 in 1 million	1 in 2.2 million	NAT + Serology
India	1 in 38,000	1 in 11,000	1 in 27,000	Serology (limited NAT)
Nigeria	1 in 12,000	1 in 6,000	1 in 18,000	Serology only

Residual risks of HIV, HBV, and HCV transmission per transfused unit in selected countries, based on screening methods and infrastructure (adapted from WHO and national hemovigilance reports).

contaminations [18, 19]. Additionally, growing awareness between healthcare experts and the general public about TTIs is vital for guaranteeing more reliable transfusion practices [20, 21]. While nations accompanying healthy blood security agreements have created significant progress in lowering TTI risks, the aim of attaining a zero-risk transference remains a complete global objective [22-25].

Literature Review

Transfusion-transmitted infections (TTIs) have been a longstanding concern in the field of transfusion medicine. Outbreaks of HIV and hepatitis viruses linked to blood transfusions have notably shaped global standards for donor screening and blood safety [2, 6]. Despite significant advancements in blood safety, TTIs continue to be prevalent, especially in low- and middle-income nations where infrastructure is limited and routine screening is less robust [9]. Research indicates that the lack of advanced diagnostic methods like nucleic acid testing (NAT) in these regions increases the risks of infections such as HIV, HBV, HCV, and syphilis [4, 8].

The introduction of NAT has greatly enhanced the detection of viral agents in high-income countries, decreasing the diagnostic window and improving transfusion safety [7, 22]. However, reliance on less sensitive methods like serological testing in resource-constrained areas allows for undiagnosed infections to persist. Studies comparing countries that fully implement NAT with those that do not highlight a significant difference in residual TTI risks [11, 3].

Alongside traditional pathogens like HIV, HBV, and HCV, newer infectious agents such as West Nile virus, Babesia microti, and Zika virus have also emerged as risks in specific geographical regions [15]. Both WHO and ECDC have stressed the importance of continuous monitoring, early detection of emerging pathogens, and the need for standardized global policies to improve blood safety [1, 23].

Despite these international recommendations, many countries still face challenges in applying these strategies effectively. Experts argue for greater investment in laboratory infrastructure, donor deferral protocols, and national hemovigilance systems to address the ongoing risk of TTIs [19,18].

Research Method

This study utilized a narrative review approach to examine the prevalence, transmission pathways, detection methods, and prevention strategies for transfusion-transmitted infections (TTIs). A comprehensive literature search was conducted using major academic databases such as PubMed, Scopus, and Web of Science, focusing on peer-reviewed articles published between 2015 and 2024. The search terms included "transfusion-transmitted infections," "blood safety," "donor screening," "TTI prevention," and "hemovigilance." Criteria for inclusion were studies involving human subjects, publications in English, and those addressing major pathogens involved in blood transfusion risks (HIV, HBV, HCV, syphilis, malaria). Grey literature, including reports from global health organizations such as WHO, ECDC, and FDA, was also incorporated to provide the most current epidemiological data and recommendations.

Results

The review confirmed that TTIs remain a significant challenge, especially in low- and middle-income countries (LMICs), where insufficient donor protection and limited access to advanced diagnostic methods exacerbate the problem. HIV, HBV, and HCV continue to be the most frequently identified pathogens. In nations with advanced screening methods such as nucleic acid testing (NAT), the diagnostic window for TTIs has been significantly reduced. In contrast, LMICs rely heavily on serological testing, which increases the residual risk of undiagnosed infections. The residual risks for transfused units are as follows: HIV (1 in 1.9 million), HCV (1 in 1.6 million), and HBV (1 in 280,000). Emerging pathogens, such as the Zika virus, West Nile virus, and Babesia microti, have also been identified as new threats to transfusion safety (Table 1) (Figure 1).

Discussion

Despite advancements in blood safety protocols, transfusion-transmitted infections (TTIs) continue to present significant challenges worldwide. High-income countries have successfully minimized the risks associated with TTIs by implementing advanced screening techniques, such as nucleic acid testing (NAT), which dramatically shortens the diagnostic window and improves detection rates. However, a disparity remains between high-income and low- and middle-income countries (LMICs), where access to these

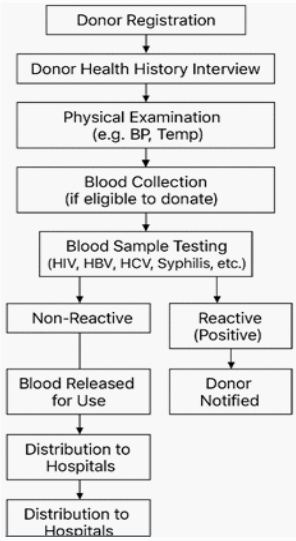

Figure 2: Flowchart of Blood Screening and Donor Deferral Process. **Source:** World Health Organization (WHO) blood safety guidelines.

advanced technologies is limited. The reliance on serological testing in LMICs increases the residual risk of undiagnosed infections, further exacerbating the problem.

In addition to traditional pathogens like HIV, hepatitis B, and hepatitis C, the emergence of new infectious agents, such as West Nile virus and Zika virus, highlights the ongoing need for continuous surveillance and adaptation of screening protocols. Global cooperation and the sharing of knowledge and resources could help bridge the gap between countries with well-established blood safety measures and those still struggling to implement effective strategies.

The role of hemovigilance systems in early detection and response to transfusion-related infections cannot be overstated. These systems, which monitor and assess the safety of blood products, are vital in identifying adverse events and ensuring that the quality of blood products is maintained. Countries with robust hemovigilance programs have been able to respond quickly to emerging threats, minimizing the impact on public health.

Despite these advancements, the goal of achieving zero-risk transfusion remains a long-term objective. Continued efforts to improve infrastructure, enhance training, and invest in diagnostic technologies are critical for reducing the burden of TTIs. Public awareness campaigns are also essential to encourage voluntary, non-remunerated blood donation, which has been associated with lower rates of TTIs compared to paid donations.

Conclusion

Transfusion-transmitted infections remain a persistent threat to global blood safety, particularly in low- and middle-income countries where inadequate infrastructure and limited access to modern diagnostic techniques contribute to residual risks. Although advances such as nucleic acid testing (NAT) have significantly reduced these risks in high-income nations, substantial disparities still exist in the global response to TTIs.

To address these challenges, it is essential to strengthen blood safety systems through international collaboration, investment in laboratory infrastructure, and the implementation of comprehensive hemovigilance programs. Additionally, raising awareness among healthcare professionals and the general public about TTIs and promoting voluntary, non-remunerated blood donation are crucial steps in ensuring a safer blood supply.

While a zero-risk transfusion remains an ideal goal, ongoing efforts to improve screening, detection, and education will continue to reduce the burden of TTIs worldwide. A coordinated global effort is required to ensure the safety of blood transfusions and protect the health of patients worldwide.

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Declaration of Interest

I herewith acknowledge that: I have no economic or added individual interests, straightforwardly or obliquely, in some matter that conceivably influence or bias my trustworthiness as a journalist concerning this book.

Conflicts of Interest

The authors profess that they have no conflicts of interest to reveal.

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