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Review article

The transfusion-transmitted infections, unveiling the novelist screening approaches

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ABSTRACT

Background: Transfusion-transmitted infections (TTIs) are defined as any bacterial, viral, or parasitic pathogen that can be transmitted through whole blood, platelets, or RBCs infusions to recipients for any medical or health conditions such as traumas, cancer diseases, or emergency cases. There are many medical and health problems attributed to the TTIs occurrence. Life threatening viruses that can be transmitted by transfusion such as HIV, HBV, and cytomegaloviruses (CMV). The data search in this review was carried out using different search engine such as Web of Science, Science Direct, Google Scholar, PubMed, and Scopus to find that many TTIs were previously detected among blood donors and in blood transmission of *Treponema pallidum*, HCV, HBV, or HIV, therefore, many screening approaches must be performed in blood banks to prevent, control, and decrease the incidence of these pathogen transmissions starting from enzyme-linked immunosorbent assay (ELISA), nucleic acid amplification testing (NAT), or polymerase chain reactions (PCR) to reduce the risk of transmission these infections to people with or without symptoms of infections. Therefore, this study aims to report, summarize, and unveil the most reported pathogens that can be transmitted through blood transfusion and the main screening approaches implemented by authorities and blood banks. Some regulations must be set by WHO to early screen blood donors and prevent the transmission of any pathogen to recipients.

Introduction

Blood donation is of paramount importance in global healthcare, with over 100 million units contributed annually [1]. Blood donation is crucial for patients undergoing surgery, suffering from trauma, and managing chronic diseases like cancer [2]. A blood transfusion entails the transfer of blood or a blood component from a healthy donor to an ill recipient. Transfusions are utilized to control and treat numerous diseases, improve the blood's oxygen transport capability [3], replenish blood volume [4], and correct coagulation disorders. The Food and Drug Administration (FDA), city health agencies, and organizations such as the American Red Cross and the American Association of Blood Banks (AABB) meticulously regulate the collection, transit, and storage of blood and its components. These laws were developed to protect both donors and receivers against infections, encompassing bacterial, parasitic, and viral risks linked to blood donation and transfusion [5-7].

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Transfusion-transmitted infections (TTIs) denote infections that can be conveyed via blood transfusions, including viral agents such as hepatitis C (HCV) [8], hepatitis B (HBV) [9], and human immunodeficiency virus (HIV), as well as bacterial and parasitic infections like malaria [10].

While blood transfusions provide considerable benefits, it is essential to recognize their intrinsic hazards [11]. Due to the widespread occurrence of hepatitis viral and HIV infections, numerous individuals may remain asymptomatic and inadvertently transmit these viruses via blood donation, potentially resulting in serious TTIs [12], particularly in regions with insufficient blood donation screening measures [13]. These pathogenic agents pose a significant risk in blood transfusions, jeopardizing recipients' health and resulting in TTIs [14].

The World Health Organization (WHO) is acknowledged for improving blood transfusion services during the previous two decades [15]. This has led to improved recruitment of voluntary donors and increased testing capabilities for significant transfusion-transmitted illnesses, especially in disadvantaged countries in Asia and Africa [16-18]. A multitude of transfusion safety research indicates that the incidence of TTIs among donors remains high. Due to the high prevalence of TTIs, it is essential to establish focused blood donation initiatives to minimize the rejection of blood units [19].

In developing countries, numerous safety requirements reduce the danger of TTIs, and these protocols include donor selection (restricting imported and window period infections), skin disinfection [20], diversion bags (reducing bacterial contamination during blood donation), donation screening [21], specialized processing methods (such as pathogen reduction and leukodepletion), along with post-donation and post-transfusion notifications [22]. These screening strategies may mitigate the risk of TTIs and hence improve patient safety protocols [23]. Therefore, this review aims to report, summarize, and unveil the most reported pathogens that can be transmitted through blood transfusion and the main screening approaches implemented by authorities and blood banks.

Materials and Methods

The data search in this review was carried out using the Web of Science, Science Direct, Google Scholar, PubMed, and Scopus search engines with searching for all studies in English language discussed the TTIs and their prevention approaches through the last 10 years. These databases were the most trusted search engines used to investigate the reports regarding this topic with more relevant data. Using the previously mentioned search engines that were identified through a series of brainstorming and searching a thesaurus, the database, and preexisting knowledge on the topic. Subsequently, the results were screened based on the study aim and these criteria allowed a broad search to be conducted while keeping the scope as precise as possible.

Bacterial infections

Treponema pallidum

Treponema pallidum is an unconventional bacterium that causes syphilis. The inaugural documented instance of transfusion-transmitted syphilis transpired in 1915 [24]. As of 1941, 138 instances had been documented in previous literature, predominantly at the early or secondary stages of the disease in donors [25]. *T. pallidum* may exist in the bloodstream, albeit its levels are inconsistent, and bacteremia is frequently transient, even after recent exposure [26,27]. The bacterial load in the bloodstream may affect transmission risk; passively transfused reagins were undetectable when the initial titer was <1:8, and in recipients from units with titers between 1:9 and 1:6, the passively transferred antibodies became undetectable after 11 days [28]. The transmission risk of syphilis may be increased by platelet concentrates, often maintained at room temperature or transfused immediately after collection [29]. The likelihood of transfusion-transmitted syphilis is markedly increased in underdeveloped nations with constrained blood resources, where blood is sourced from familial donors and utilized within hours [30].

Gram-positive bacteria

Platelet products stored at room temperature, typically between 19 to 23 °C, pose the highest risk of bacterial infection among blood products [31]. Platelet products primarily harbor gram-positive bacteria, notably beta-hemolytic *Streptococci*, with an incidence of 39% to 48%; coagulase-negative *Staphylococci*, with an incidence of 20% to 25%; and *Staphylococcus aureus*, with an incidence of 5% to 11% [32] **(Table 1).**

Gram-negative bacteria

Blood collection banks often maintain units of red blood cells at temperatures ranging from 1 to 5 °C, which promotes the proliferation of gram-negative rods [33]. The predominant pathogen detected in red blood cell units is *Yersinia enterocolitica*, which is significantly linked to sepsis after red blood cell transfusion [34] **(Table 1).**

Viral infections

Viral invasion to transfusion and blood bags is the most crucial microbial invasion among TTIs. Many viruses can be transmitted through transfusions and then multiply in them to cause much harm to recipients afterwards **(Figure 1).**

Hepatitis viruses (A-E)

All hepatitis viruses (A to E) can be transmitted via blood transfusion, with HBV and HCV representing the most significant risks to blood safety. This results from their capacity to induce persistent (often asymptomatic) infections linked to long-term consequences, including liver cirrhosis and hepatocellular carcinoma [35,36]. Consequently, they are linked to increased morbidity and mortality compared to hepatitis A and E viruses in developed nations [37].

In certain countries, a significant percentage of blood transfusion donors and receivers have been identified as infected with HBV and HCV [37]. The notification system is intended to track incidence rather than prevalence [38]; hence, the prevalence of viral hepatitis types that may lead to chronic infection remains ambiguous, since the infection may cure spontaneously, be treated in the case of HCV, or individuals may relocate or die [39-41].

Human immunodeficiency virus (HIV)

The transmission of HIV by the transfusion of contaminated blood products was recorded in the United States in 1982 [42]. The HIV infection, leading to acquired immune deficiency syndrome (AIDS), poses a significant global public health concern [43]. The principal risk factor for HIV transmission is blood transfusion, with over 90% of recipients of contaminated blood testing positive during follow-up, as blood has a significantly higher concentration of HIV compared to other transmission pathways [44].

West Nile virus (WNV)

The WNV is a flavivirus transmitted by mosquitoes, primarily spread among avian species, with humans acting as incidental hosts [45]. In August 2002, owing to theoretical concerns regarding the transmission of WNV via blood transfusions, the FDA instructed blood establishments and health departments to surveil individuals infected with West Nile virus who had donated blood in the week preceding the onset of their illness, as well as those exhibiting unexplained fever-associated meningitis or encephalitis following a blood transfusion [46-48].

Human T-lymphotropic virus (HTLV)

HTLV is dispersed worldwide but shows increased incidence in some places, such as southern Japan, the Caribbean, certain parts of South America, the Middle East, Sub-Saharan Africa, Australia, and Melanesia [49]. The HTLV virus can be transmitted via blood transfusion, and most infected patients are asymptomatic, frequently remaining oblivious to their status. This suggests the possible presence of asymptomatic persons harboring the virus who may inadvertently donate blood [50]. Approximately 60% of patients develop anti-HTLV after receiving cellular blood products carrying the virus, so establishing its transmission [51]. Given the considerable danger of transmission from an infected donor, there is considerable interest in the incidence of HTLV among blood donors [52,53].

Cytomegalovirus (CMV)

Human CMV was identified fifty years ago as a possible etiological agent for the mononucleosis-like post-perfusion syndrome following fresh blood infusions after cardiac surgery. Transfusion-transmitted cytomegalovirus (TT-CMV) primarily induces moderate febrile symptoms in immunocompetent receivers [54]; however, it significantly exacerbates outcomes in immunocompromised persons, especially following organ transplantation [55].

Zika virus (ZIKV)

The ZIKV was first identified in a patient who received a platelet concentrate transfusion, with probable transmission via transfusion recorded [56]. It is imperative to assess the actual risk of Zika virus transmission via blood or blood components and to determine the necessary preventive measures to mitigate this risk [57].

SARS-CoV-1

Despite the absence of documented COVID-19 transmission by transfusion, the blood transfusion service persists in employing pre-donation and post-donation protocols to mitigate

risk [58]. It is essential to ascertain whether the SARS-CoV-2 virus can be spread through blood transfusion, given that several persons may be asymptomatic carriers and could potentially donate blood [59]. Numerous instances have been documented in which unique viral RNA was identified in the serum of COVID-19 patients; these observations imply that blood donation may be a neglected route of transmission [60]. The AABB and the Centers for Disease Control and Prevention have not issued any SARS-CoV-2-related guidelines for blood collection centers at this time [61].

Parvoviruses

Parvovirus B19V is a prevalent contaminant in blood and plasma donations; its diminutive size and absence of a lipid envelope confer resistance to conventional viral inactivation techniques [62], hence heightening the risk of transmission via blood products. B19V's significant resistance characteristics render it an ideal model for investigating future developing viruses that may taint blood supplies [63,64]. The prevalence of B19 viremia among blood and plasma donors varies from 0.003% to 0.88%, contingent upon the sensitivity of the utilized nucleic acid amplification testing (NAT) method and the timing of testing during an epidemic [65]. Minimal concentrations of B19V DNA, between 11 and 100 IU or geq/mL, can coexist with anti-B19V IgG and may persist for 3 to 5 years in immunocompetent blood donors [66].

Parasitic infections

Transfusion-transmitted parasites are also important to be studied, monitored, and screened, although a few types of parasites can be transmitted by transfusion **(Figure 2)**, it is crucial to be early screened to prevent further health damage to blood receiers.

Plasmodium malariae

Transfusion-transmitted malaria (TTM) is an unintentional infection caused by Plasmodium spp. that occurs when whole blood or blood components from a malaria-infected donor are transfused to a recipient [67]. The incidence of transfusion-transmitted malaria in non-endemic nations is negligible owing to rigorous donor screening protocols. Plasmodium falciparum, Plasmodium vivax, and Plasmodium malariae are the species most frequently recognized in TTM which presents a rare but considerable risk, and the optimal strategy to alleviate this danger in non-endemic regions, without unjustly deterring blood donors [68.69], continues to be a subject of debate. Semi-immune persons present the most significant obstacle for TTM screening, as they may become asymptomatic carriers with low parasite density, which current direct diagnostic approaches find difficult to detect [70].

Babesiosis

Human babesiosis is a globally emerging protozoal illness caused by several intraerythrocytic protozoa, primarily transmitted by hard-bodied ticks and through blood transfusion. Transfusion-transmitted babesiosis (TTB) was initially identified in 1979, a decade after the discovery of the first tick-borne disease [71]. The risk of TTB fluctuates significantly owing to the irregular distribution of babesiosis infections, especially in endemic areas. Patients afflicted with TTB frequently exhibit severe illness, with a death rate of approximately 20% [72].

Trypanosoma cruzi

T. cruzi can be transferred by blood transfusions from chronically infected, predominantly asymptomatic persons [73]. The acute phase of post-transfusion infection has an incubation period of 20 to 40 days, with a variability of 8 to 120 days. In nations with indigenous or immigrant populations susceptible to illness, the blood supply must be safeguarded by employing appropriate measures [74]. The initial documentation of *T. cruzi* infection transmission via blood transfusion occurred in 1936 by Salvador Mazza in Argentina. The parasite may be identified in the bloodstream of infected individuals for several years [75]. Consequently, transmission can occur by transfusion even if the donation occurs years after the disease's beginning. *T. cruzi* can persist in blood components under typical storage conditions (19 days at 3-4 °C for red blood cells, 245 days at 21 °C for platelets) and exhibits resistance to freezing. Consequently, the infection may be conveyed to the receptors of transfused red blood cells, fresh frozen plasma, platelets, granulocytes, or cryoprecipitates [76]. The characteristics of the transfused component and the recipient's immunological condition influence the likelihood of transmission; indeed, not all patients receiving infected units will get the sickness [77].

Leishmania

Human visceral leishmaniasis is a vector-borne parasitic disease resulting from obligate intracellular protozoa of the genus *Leishmania* [78].

The risk of transfusion-transmitted leishmaniasis (TTL) has been emphasized about the potential spread of *Leishmania* by asymptomatic individuals in the healthy blood donor population. Extensive studies on the incidence of asymptomatic carriers among blood donors have been undertaken worldwide, with proportions ranging from 0% to 35% [79], dependent on the testing methods utilized and the sample size examined. In vitro studies have shown that, under typical blood bank storage conditions, transfusion blood products contaminated with *L. tropica* or *L. donovani* remain viable for at least 21 days following donation. Packed red blood cells, frozen-deglycerolized red blood cells, platelet concentrate, and whole blood have been recorded as involved [80]. In contrast, no anticipated published reports on fresh frozen plasma have surfaced. Intracellular parasites have a longer lifespan than stationary-phase extracellular promastigotes or free amastigotes [81]. The parasites survive for 25 days as intracellular organisms within monocytes in the red blood cell fraction saved at 3-4 °C, for 30 days in the glycerol-frozen red blood cell fraction, for 5 days in the platelet fraction maintained at 23 °C, and for 28 days in unprocessed whole blood preserved at 3-4 °C [82]. To determine the minimum concentration of L. tropica necessary to contaminate 1 ml of blood, serial dilutions with specified numbers of intramonocytic amastigotes per milliliter were cultured in whole blood at 3-4 °C; predefined aliquots were removed daily to assess parasite presence [83,84].

Screening of transfusion-transmitted infections

The WHO advocates for the utilization of a highly sensitive and specific test to screen populations with a high frequency of bacterial illnesses such as syphilis [12], thereby reducing the risk of transmission via blood transfusion. Blood centers have transitioned from non-treponemal to treponemal testing due to the advantages of automation and the reduction of subjective errors [62]. A serologically tested TTI approved by the WHO is mandatory. The risk of syphilis transmission through blood transfusions has been mitigated due to rigorous screening standards and enhanced diagnostic techniques. The Carbogen Rapid Plasma Reagin (RPR) card test is a standard syphilis screening technique that employs a flocculation assay, commonly used in all blood centers following manufacturer protocols [74]. The venereal disease research laboratory (VDRL) test detects antibodies against the cardiolipin antigen in people with active syphilis. The RPR and VDRL tests may produce positive findings for 1 to 2 years following treatment in patients previously infected. The current treponemal assays comprise enzyme immunoassays (EIA) [13], Treponema pallidum micro hemagglutination assays (MHA-TPA), fluorescence treponemal antibody absorbed assays (FTA-ABS), and Treponema pallidum particle agglutination assays (TP-PA) [7]. These assays identify antibodies that are specific to treponemal antigens. Treponemal testing will consistently produce positive findings for a patient's lifetime, regardless of treatment [31.45]. The reverse algorithm for syphilis screening has recently been implemented using the enzyme-linked immunosorbent assay (ELISA). This method has exhibited superior accuracy, efficacy, and dependability in identifying antibodies against *T. pallidum* in blood donors across multiple developing countries [85]. This test kit is a third-generation double antigen sandwich ELISA designed for the detection of antibodies (IgG and IgM) against *T. pallidum* in human serum or plasma. The performance evaluation report from the manufacturer asserts 100% sensitivity [71].

Numerous methods have been developed to avert transfusion-transmitted infections resulting from bacterial contamination [86]. Most donation centers do bacterial cultures on platelet products obtained from individual donors [18]. The institution releases the platelets if the cultures exhibit no growth after 24 to 30 hours. Platelets from different donors may undergo screening for bacterial contamination by hospital transfusion services [37]. Supplementary procedures can be categorized into two primary groups: the production of platelet products and the application of fast diagnostic tests [51] BacT/ALERT® (BioMérieux) has obtained FDA certification for platelet quality control; nevertheless, commercial kits like the BacTx® assay (Immunetics) and the Platelet Pan Genera Detection Test (Verax Biomedical) are also accessible within the same category. Despite variations in acceptance among nations, no technique has eliminated transfusion-transmitted illnesses resulting from bacterial contamination [12,31,86].

In most developed countries, donor blood products are tested for HBV using HBsAg screening [87]. To alleviate potential challenges in identifying low concentrations of HBsAg in chronic HBV carriers, donation facilities may additionally employ

assays for the detection of anti-HBc [41]. Anti-HBc antibodies emerge early in the infection and persist consistently positive. NAT for HBV is crucial for detecting HBV DNA in individuals with chronic infection, undetectable HBsAg levels [51], and inconclusive anti-HBc findings. HBsAg establishes a detection window of 3 to 40 days, whereas NAT reduces this window to 3 to 4 weeks. Anti-HBc tests may yield positive results within one week of infection; nevertheless, they possess a false positive rate of 1.1% [62]. Donation centers assess for HCV using assays for anti-HCV antibodies and nucleic acid testing for HCV RNA. The standard procedure for detecting HCV infection is mini-pool nucleic acid testing (MP NAT), which assesses small aliquots from donations of 4 to 16 donors as a combined sample. The current methodology has a duration of one to two weeks. MP NAT also detects HIV RNA and has replaced p24 antigen testing in donor blood screening [78,81]. The window period for HIV detection by MP NAT is around 11 days. NAT is the most efficient screening method for West Nile Virus and Zika virus. Donation facilities utilize individual NAT testing for WNV instead of pooled testing because of the heightened infection risk associated with patients exhibiting low-level viremia. Current antibody detection assays recognize CMV and HTLV [43].

Consequently, when evidence of blood-borne HIV infection increased, initiatives to enhance the blood supply and ensure transfusion safety were implemented. Since the onset of the pandemic [45], significant advancements have been achieved in comprehending and mitigating the risk of HIV [28]. Hospitals implement protocols aligned with national and international guidelines for effective blood screening and rigorous donor selection criteria, [61] which include assessing donors' HIV risk behaviors and testing each blood unit for antibodies, to avert HIV transmission. Challenges persist in the identification of transfusion-transmitted HIV infection [44]. For instance, blood may be donated just after an individual becomes infected, during which the donor is infectious but has not yet produced HIV antibodies that would yield positive laboratory test results [12]. This interval is referred to as the "window period." During the serological window period, the virus present in the bloodstream may be transmitted to the receiver, even if the serological test result is negative [43]. The primary HIV blood screening test, the ELISA, was established in 1985 and evaluated solely HIV antibodies. The implementation of NAT has reduced the window period for detecting probable HIV infection to 4 to 12 days [85,86].

The implementation of universal leucoreduction (the extraction of leukocytes from blood or blood components designated for transfusion) in various nations has ignited a discussion regarding the supplementary benefit of employing exclusively CMV-seronegative blood for patients susceptible to TT-CMV [11,87]. Numerous hospitals continue to maintain parallel stockpiles of blood products from CMV-seronegative donors for at-risk patients, despite the widespread implementation of universal leucoreduction in nearly all countries [61].

Highly sensitive NAT is utilized for the routine screening of blood donations ZIKV RNA, while amotosalen (A) combined with ultraviolet A light pathogen reduction technology (INTERCEPT® Blood System for Platelets and Plasma) acts as an alternative to NAT to mitigate the risk of transfusion-transmitted ZIKV [12,73].

Investigations into laboratory screening indicate that *B. microti* antibody and/or PCR assays may serve as useful screening methods for the prevention of TTB [58]. *B. microti* infects erythrocytes, and its identification can be directly verified through microscopic analysis of thin blood smears or by amplifying parasite DNA from whole blood or an erythrocyte fraction. Many PCR assays exhibit superior sensitivity compared to thin blood smears and are typically regarded as confirmatory tests [87]. The most dependable serological test for clinical diagnosis is the immunofluorescence assay (IFA), which utilizes erythrocytes from parasitemic hamsters that carry *B. microti* whole-cell antigens [88].

Microscopy is the conclusive diagnostic technique for malaria; nevertheless [13], it demonstrates inadequate sensitivity in identifying asymptomatic infections with low parasitemia [61]. The identification of *P. falciparum* is performed via the analysis of thick blood smears. The utilization of molecular biology techniques has been suggested to enhance the effectiveness of malaria diagnosis in blood donors [74]. The molecular diagnostic method utilizing real-time PCR targeting mitochondrial DNA (mt-qPCR) has been refined to detect *P. falciparum*, *P. vivax*, and *P. malariae*. The mt-qPCR technique has considerable analytical sensitivity

[25], effectively identifying potentially compromised donors. Incorporating mt-qPCR testing into routine screening of asymptomatic carriers could reduce the incidence of transfusion-transmitted malaria in blood banks [85]. The heightened occurrence of ambiguous serological outcomes and the evaluation of the effectiveness of blood cultures and several commercial assays, such as indirect immunofluorescence, ELISA [13], and hemagglutination assays [21]. These methods exhibit effectiveness in detecting anti-Trypanosoma cruzi antibodies [21,89].

Vaccines used to prevent TTIs

Unfortunately, there are few vaccines can be used and administrated to population for controlling some of TTIs, as most of these TTIs have no vaccines yet, besides, the high costs of giving these vaccines, the availability of these vaccines is not high yet, the following table summarizes the most applied and available vaccines against some of TTIs.

Egyptian ministry of health efforts to combat TTIs

In 2020, the Ministry of Health and Population (MOHP), in collaboration with stakeholders, developed the "Plan of Action for the Prevention, Care & Treatment of TTIs, specifically [90], the Viral Hepatitis, Egypt" which focuses on the seven main components of viral hepatitis prevention and control: surveillance, infection control, blood safety, hepatitis B virus (HBV) vaccination, care and treatment, communication, and research [91]. The PoA highlights the important goals and objectives of the MOHP's viral hepatitis program and reflects the MOHP's commitment to controlling the viral hepatitis epidemic by preventing new infections. As decalred by WHO, The revised National Standards for Blood Transfusion Services 2023 is a result of the efforts of the Blood Safety Taskforce formed under Egypt's national viral hepatitis, syphilis, and CMV programs, with the collaboration of all service providers including the Ministry of Health and Population, Ministry of Higher Education, Ministry of Defense, Ministry of Interior, the private sector, VACSERA and the Egyptian Red Crescent [92]. The frequent screening for Egyptian population for communicable diseases, and the inspection on blood banks about the regular and routine screening of blood bags from donors as well as the direct communication to donors to inform them if they have any TTIs is also applied [90].

Table 1. Different bacterial strains isolated and considered as TTIs

Bacteria class	Isolates detected
Gram-positive	*Streptococcus viridans* [35]
	Streptococcus bovis [12]
Gram-negative	*Serratia spp*. [24]
	Pseudomonas fluorescens [7]
	Enterobacter spp. [2]
	Escherichia coli [14]

Table 2. Vaccines used to prevent and combat TTIs transmission

Vaccine name	Number of doses	Regimens	Notes
HAV	Two doses [12]	Children are given a 2-dose series typically at age 12 to 23 months and 6 to 18 months after the first dose [14].	Havrix [12].
	Three doses [26]	Children are given 3-dose series 0 and 6 to 12 months [41].	Vaqta [21].
HBV	Three doses by intramuscular route [11].	Birth, one month, and 6 months doses [85].	Available in eastern and middle east regions [90].
	Four doses by intramuscular route [34].	24- of birth, 6 weeks, 14 weeks, and 24 weeks of birth doses [37].	
Malaria	Four doses [15].	They are currently indicated for children, with the first dose given at 5 months of age. The first 3 doses are administered monthly, and the third should be completed by 9 months of age [44].	It is called RTS,S/AS01 vaccine [51].
Babesiosis	Two doses [29].	First injection from 6 months of age, second injection 3-6 weeks later	Nobivac Piro [51].
SARS-Cov2	Two doses' series plus a third (booster) dose by intramuscular administration [18].	With one to 3 months regimen [48].	mRNA/lipid nanoparticle vaccines (BNT162b2 and mRNA-1273) [71].
	Initial dose by intramuscular route followed by booster dose [35].	One month regimen [31].	Adenovirus-vectored vaccine (Ad26.COV2·S COVID-19 vaccine) [24].

Figure 1 A summary of transfusion-transmitted viruses detected among blood donors [1,12,25,31,35]

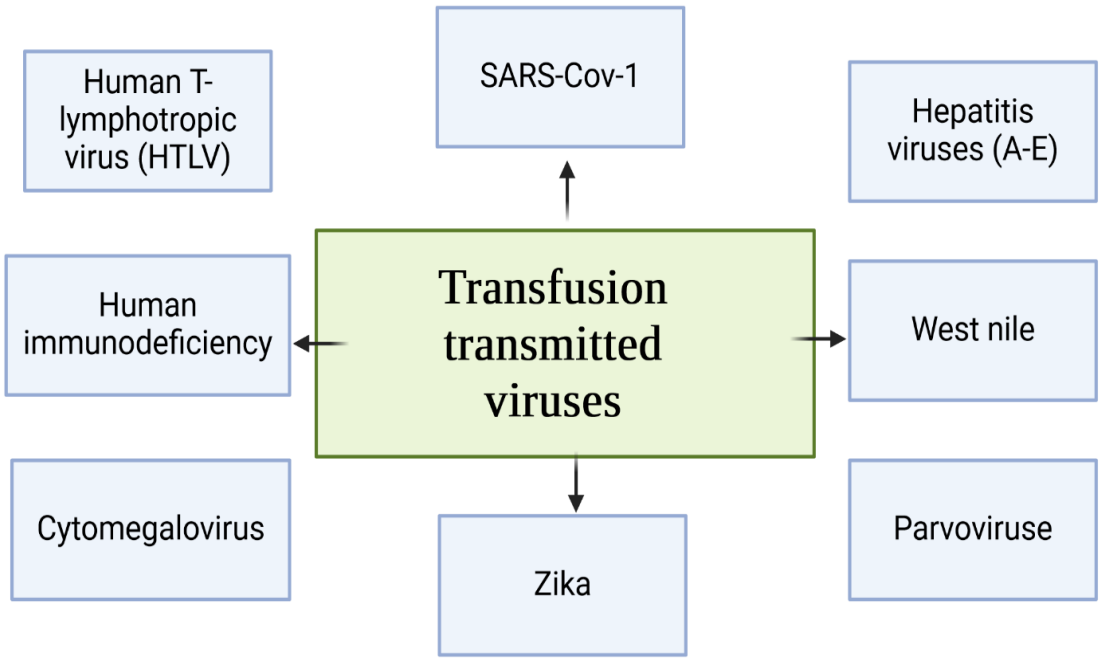
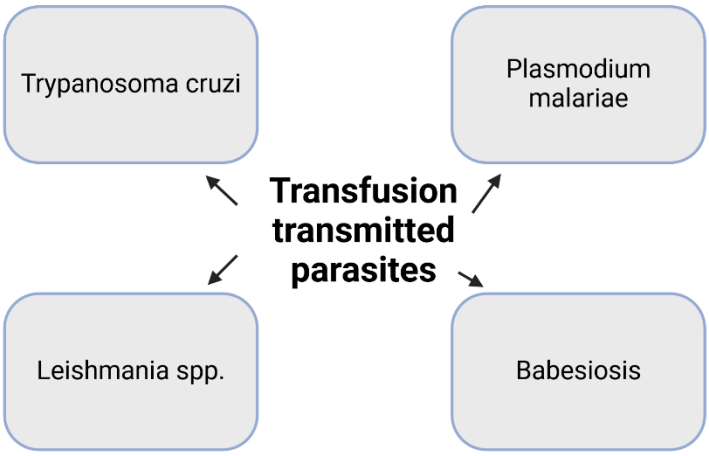


Figure 2 A summary of transfusion-transmitted parasites detected among blood donors



Conclusion and Recommendations

In conclusion, many pathogens can be transmitted through whole blood, platelets, or RBCs transfusion. Viral pathogens such as HBV, HCV, and HIV are the most reported pathogens invading and transmitted through transfusion. Several screening approaches can be implemented to early screen the TTIs in blood components even among asymptomatic donors, the highly sensitive NAT is the most widely and effective screening procedure used to potentially detect any TTIs. Some regulations must be set by WHO to early screen blood donors and prevent the transmission of any pathogen to recipients.

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