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HIV Screening in Blood Donors: Addressing Global Disparities and Advancing Technologies

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ABSTRACT
The review paper explores the intricate relationship between blood donation and the incidence of HIV, emphasizing the critical importance of advanced screening technologies and public health strategies in ensuring blood safety. The paper highlights how nucleic acid testing (NAT) has significantly enhanced the detection of HIV among blood donors, thereby reducing the risk of transfusion-transmitted infections. Despite these advancements, challenges persist, particularly in low-resource settings where the implementation and maintenance of comprehensive screening methods are hindered by limited resources. The review discusses how demographic and socioeconomic factors, along with social attitudes and misconceptions about HIV and blood donation, impact donor participation and blood supply safety. It underscores the necessity for public health strategies that address these issues through targeted interventions and education. Furthermore, the paper advocates for international collaboration and support to address global disparities in blood donation practices. Ultimately, the review calls for a coordinated effort involving advanced screening technologies, strategic public health interventions, and community engagement to effectively mitigate the risks associated with blood donation and HIV.

Keywords: Blood Donation, HIV/ AIDS, HIV Screening, Rapid diagnostic tests (RDTs), Nucleic Acid Testing (NAT), Enzyme-Linked Immunosorbent Assay (ELISA).

Background of the Study
HIV is a member of the lentivirus subgroup within the retroviruses. It is the virus responsible for causing HIV infection, which, if not treated, can advance to acquired immunodeficiency syndrome (AIDS) in its later stages [1]. AIDS is a pathological condition characterized by immunodeficiency, resulting in susceptibility to opportunistic infections and cancers. Untreated individuals with HIV infection typically have an average lifespan about 10 years [2].HIV can be transferred via sexual intercourse, blood transfusion, sharing contaminated needles, and from an infected mother to her baby during pregnancy. HIV can be transferred through sexual intercourse via direct contact with blood, semen, and vaginal secretions. Furthermore, the infant may acquire an infection from the mother during pregnancy and delivery, because of being exposed to the mother's blood or vaginal fluid.
Blood transfusions are lifesaving, but they also pose a danger of transmitting illnesses like HIV, HCV, and HBV. These transfusion-transmitted infections (TTIs) remain as major problems, especially in developing countries with limited resources [3]. It is critical to properly screen blood donors for viral indications to avoid transfusion-transmitted infections. Sensitive HIV tests, like enzyme-linked immunosorbent assay (ELISA), Chemiluminescent Immunoassay (CLIA), and nucleic acid testing (NAT), are often used when resources are limited. Rapid diagnostic tests (RDTs), on the other hand, are easy to get and do not cost much [3]. Even though World Health Organization WHO has a HIV testing services HTS guideline, many of countries have their own guidelines that commensurate with their health system and economic situations. Many of HIV testing services HTS in the world are similar, however the level of quality is different from country to others. Although Saudi Arabia has a relatively low prevalence of HIV compared to Western countries, the accuracy and reliability of HIV screening tests for blood donors remain unknown. This gap in knowledge presents a significant risk to blood safety, as transfusion-transmitted infections can have severe consequences.

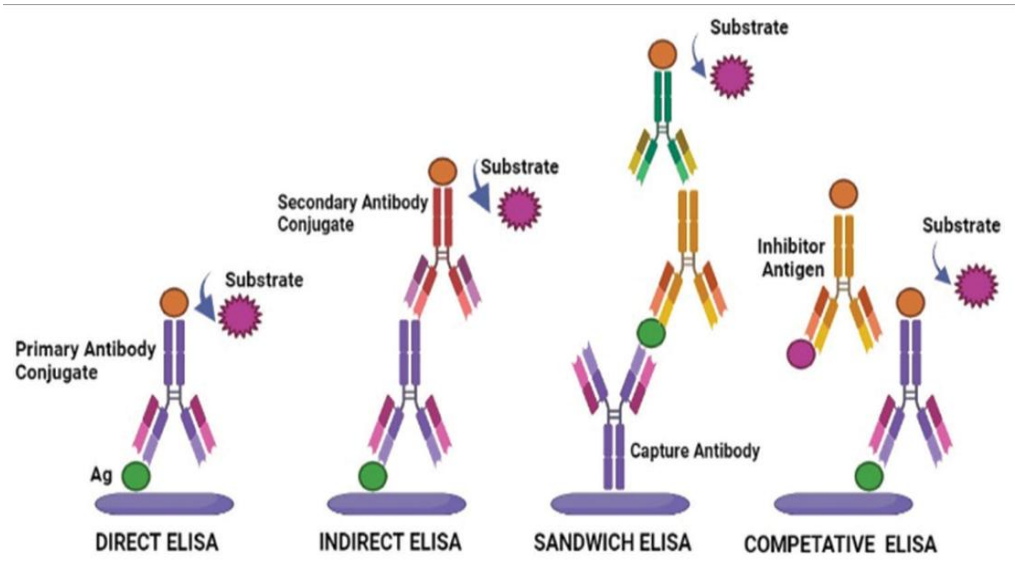

Figure 1. ELISA Types and Principles. ELISA: Enzyme-linked Immunosorbent Assay

RESEARCH METHODOLOGY

In this review paper, the literature search of previous studies was conducted by expending electronic databases for example PubMed, Ovid, Google Scholar, EMBASE, and Cochrane Central Register of Controlled-Trials. These databases were chosen for their comprehensive coverage of medical and scientific literature, ensuring a wide range of relevant studies were considered. To identify pertinent studies, a combination of specific search terms and keywords was utilized. These included terms such as "Blood Donation, HIV/AIDS, HIV Screening, Rapid Diagnostic Tests (RDTs), Nucleic Acid Testing (NAT), and Enzyme-Linked Immunosorbent Assay (ELISA). These keywords were selected to capture various aspects of HIV screening technologies and their application in blood donation contexts. The review focused on studies that provided insights into the effectiveness, challenges, and advancements in HIV screening methods among blood donors.

Inclusion criteria for the studies were based on their publication in peer-reviewed journals, their focus on HIV screening technologies, and their relevance to global disparities in blood donation practices. Studies that did not meet these criteria, such as those lacking rigorous scientific methodology or not directly related to HIV screening in blood donors, were excluded. Data from the selected studies were systematically extracted, focusing on the effectiveness of different HIV screening methods (e.g., NAT, ELISA, RDTs), challenges in implementing these methods, especially in low-resource settings, and the impact of demographic and socioeconomic factors on blood donation and HIV screening. The extracted data were synthesized to provide a comprehensive overview of the current state of HIV screening in blood donors and to identify gaps and opportunities for improvement. The review utilized a narrative synthesis approach to analyze the data, allowing for the integration of findings from diverse study designs. This approach facilitated the identification of patterns, themes, and relationships between blood donation practices and HIV incidence. The methodology acknowledges potential limitations, such as publication bias and variability in study quality and design, which were considered when interpreting the findings and drawing conclusions. Overall, the methodology aimed to provide a thorough and balanced assessment of HIV screening in blood donors, addressing both technological advancements and socio-economic challenges that influence blood safety globally.

Data Analysis

The data analysis for this review paper provides a comprehensive synthesis of existing research on HIV screening methods among blood donors. The analysis emphasizes the critical role of advanced screening technologies, such as Nucleic Acid Testing (NAT), in enhancing the detection of HIV and reducing the risk of transfusion-transmitted infections. Despite these advancements, the paper identifies persistent challenges, particularly in low-resource settings where the implementation of comprehensive screening methods is hindered by limited resources. The analysis further explores how demographic and socioeconomic factors, along with social attitudes and misconceptions about HIV and blood donation, impact donor participation and blood supply safety. It underscores the necessity for public health strategies that address these issues through targeted interventions and education. Additionally, the paper advocates for international collaboration and support to address global disparities in blood donation practices. Ultimately, the review calls for a coordinated effort involving advanced screening technologies, strategic public health interventions, and community engagement to effectively mitigate the risks associated with blood donation and HIV.

Correlation between Blood Donation and the Incidence of HIV

Complex and vital topics: blood donation and HIV. Global healthcare relies on blood donation for transfusions and other procedures. Patients need strict screening and testing to avoid transfusion-transmitted diseases like HIV. Regional demographics, screening technologies, and procedures affect HIV prevalence among blood donors. All parts of this topic must be explored to understand and mitigate risks[4]. Although important, blood donation can spread dangerous illnesses. HIV prevalence among blood donors remains a concern in many regions despite comprehensive screening. Nucleic acid testing (NAT) has enhanced HIV detection in blood donors by detecting viral infections earlier, reducing the window period. Modern screening procedures like NAT have reduced HIV transmission through blood transfusions. These improvements underline the need for screening procedures to meet the highest blood safety standards.[5]

Demographics can affect blood donor HIV prevalence and incidence. Donor HIV risk depends on age, gender, sexuality, and risk-taking. Studies show that HIV prevalence rates vary greatly by population, emphasizing the necessity for targeted policies and interventions. Younger donors may have distinct risk behaviors, needing age-specific measures. Socioeconomic status and education may alter donor behavior and HIV risk knowledge, affecting blood donation safety[6]. Public attitudes and conventions about HIV can affect donor behavior and blood supply safety. HIV stigma and misinformation about blood donation risks can deter donors. Hesitancy can reduce the donor pool, reducing safe blood and boosting high-risk donors. These difficulties can be solved by blood donation safety and HIV screening public health campaigns. Understanding and acceptance can lessen anxiety and boost blood donation[7].

Training and proficiency of laboratory workers affect HIV screening accuracy and reliability. Lab worker skills determine HIV testing quality. High screening standards require constant training and quality assurance to assure accuracy and reliability. Uniform protocols and training programs are essential to instruct all lab staff in HIV testing. Audits and performance reviews can also identify areas for improvement and ensure best practices[8].

Public health policy and resources affect blood donor HIV rates. Well-funded and integrated public health infrastructures improve screening and reduce transfusion-transmitted infections. Low-resource areas may struggle to implement and maintain thorough screening methods, increasing HIV transmission risks through blood donations. Due to global blood product demand, safe and sufficient blood supply requires effective blood collection and resource allocation, especially in low-resource settings. International health organizations and partnerships can help underdeveloped nations fill resource gaps[9].

Potential donors' behavior affects blood supply safety and reliability. Low donor turnout and blood supply quality might result from safety and necessity misperceptions. Safe blood donation and increased blood donation require comprehensive educational initiatives and community engagement. Public health initiatives should dispel blood donation myths and explain its benefits and safety. Engaging with community leaders and influencers helps promote trust and positive messaging[10]. HIV prevalence in the general population and subgroups affects blood donor HIV rates. Epidemiological and surveillance data on HIV prevalence can inform public health policy and interventions. Understanding HIV transmission dynamics in the general population helps health authorities improve blood donor screening and prevention measures, keeping blood suplies safe. Blood donation can be successful with epidemiologically updated screening criteria[11].

Blood donor HIV screening test sensitivity and specificity affect HIV detection rates. Antibody, antigen, and nucleic acid HIV tests identify HIV at distinct stages. HIV treatment and prevention require accurate and rapid diagnosis. To prevent HIV transmission, blood donation requires precise screening. Standardized screening and quality assurance are needed for blood supply reliability and safety. Developing new testing methods improves screening accuracy [12]. International blood donation and HIV screening rules affect blood supply safety. Regulations must be uniform and scientific to ensure fair screening. Inconsistent or strict regulations discourage donors and reduce safe blood, increasing transfusion-transmitted illnesses. Safe blood supply and rigorous screening must be balanced by public health officials. Assess and update policies to reflect technological and epidemiological.developments[13].

Public health policies and resource allocation strongly impact HIV and blood donation. Well-funded and structured public health programs improve blood donor screening and HIV reduction. Low-resource nations may struggle to maintain adequate screening and testing standards, increasing HIV transmission through blood transfusions. To reduce these differences, blood collection and resource distribution must be improved globally, especially in low-resource situations. Underserved health systems can benefit from global health organization funding and collaborations [14]. Social attitudes and misconceptions about blood donation affect donor behavior and blood supply safety, especially in high-risk populations. Public health programs must address these issues by promoting safe blood donation and accurate information. Dispelling misunderstandings and promoting blood donor involvement needs community and stakeholder engagement. Public health officials can increase donor involvement and blood supply safety by addressing social misconceptions. These projects benefit from personalized and culturally relevant communications[15].

A complex combination of screening technology, donor policies, public views, and public health interventions affects blood donation and HIV incidence. Blood donor nucleic acid testing has considerably improved HIV

diagnosis, lowering transfusion-related transmission. Laboratory staff training, screening methods, and quality assurance determine HIV test results. HIV prevalence among blood donors depends on public health strategy and resources. Well-organized public health infrastructures and screening programs can significantly reduce donor HIV prevalence[16]. However, low-resource regions may not implement and maintain thorough screening systems, increasing HIV transmission during blood donations. To reduce these differences, blood collection and resource distribution must be improved globally, especially in low-resource situations. International health organizations and partnerships can help underdeveloped nations fill resource gaps.

Social norms and beliefs affect blood donors' attitudes and behaviors, which are vital to blood supply safety. Comprehensive education and community engagement are needed to improve blood donation and safety. Public health officials can increase donor involvement and blood supply safety by addressing social misconceptions. Engaging with community leaders and influencers helps promote trust and positive messaging[17]. Finally, screening technologies, donor policies, public opinion, and public health efforts affect HIV and blood donation. Blood donor nucleic acid testing has considerably improved HIV diagnosis, lowering transfusion-related transmission. Laboratory staff training, screening methods, and quality assurance determine HIV test results. HIV prevalence among blood donors depends on public health strategy and resources. A safe and sufficient blood supply requires addressing social attitudes and misconceptions about blood donation, especially in high-risk communities. Public health authorities can enhance blood donation, minimize HIV transmission, and ensure blood supply safety by considering these factors. Blood donation and HIV screening are challenging; thus this complete strategy is needed to protect public health and avoid transfusion-transmitted diseases[18].

HIV prevalence among blood donors underscores the necessity for continued screening and public health initiatives. Although technology has improved, blood supply safety is still tough. These difficulties are exacerbated by demographic, socioeconomic, and public image and behavior disparities. Effective public health programs must address these issues through targeted interventions, education, and resource allocation[19]. HIV rates are lower with advanced blood donor screening. Early HIV detection with nucleic acid testing (NAT) has revolutionized HIV detection. Early detection reduces illness time, enhancing blood supply safety. Adopting new technologies requires extensive infrastructure and training[20].

The demographics of blood donors can disclose HIV prevalence. Younger donors may be riskier than elders. Gender-specific behaviors and social norms can also affect HIV infection. Understanding these demographics is crucial to designing donor-group-specific interventions that address their risks[21]. Social norms and public perception substantially influence donor behavior. HIV stigma and blood donation safety concerns deter donors. Addressing these concerns requires comprehensive public health campaigns promoting blood donation's benefits and safety. These ads should debunk myths, reduce stigma, and encourage blood donation. Community leaders and influencers can also convey accurate information and build trust[22]. HIV screening test accuracy and reliability require laboratory staff training and proficiency. Training and quality assurance must maintain screening criteria. Lab personnel must know the latest screening methods to avoid HIV from blood transfusions. Standardized criteria and training help screening facilities retain accuracy[23].

Screening program resources must be optimized by public health policies. Well-funded public health infrastructures improve screening and reduce transfusion-transmitted infections. However, low-resource locales may struggle to create and maintain thorough screening techniques. Global health organizations and international cooperation can help underserved regions address these disparities[24]. Education, culture, and public health messaging influence blood donors' behavior. Misconceptions about blood donation safety and awareness can lower donor numbers and quality. Public health campaigns should emphasize education to overcome these barriers and promote safe donation. Community involvement in blood donation programs might also increase participation[25].

HIV prevalence in the general population and subgroups affects blood donor HIV rates. Epidemiological and surveillance data on HIV prevalence can inform public health policy and interventions. Understanding HIV transmission dynamics in the general population helps health authorities improve blood donor screening and prevention measures, keeping blood supplies safe[26]. HIV screening methods affect blood donor HIV detection rates by sensitivity and specificity. Antibody, antigen, and nucleic acid HIV tests identify HIV at distinct stages. Preventing and managing HIV requires precise and rapid diagnosis. Standardized screening and quality assurance are needed for blood supply reliability and safety. Developing new testing methods improves screening accuracy[27].

International blood donation and HIV screening rules affect blood supply safety. Regulations must be uniform and scientific to ensure fair screening. Inconsistent or strict regulations discourage donors and reduce safe blood, increasing transfusion-transmitted illnesses. Safe blood supply and rigorous screening must be balanced by public health officials. Assess and update policies to reflect technological and epidemiological developments (Steele et al., 2020). Several factors affect blood donation and HIV incidence. Nucleic acid testing has considerably improved HIV detection in blood donors, lowering transfusion-related infection. Laboratory staff training, screening methods, and quality assurance determine HIV test results. Blood donor HIV rates rely on public health strategy and resource allocation. A safe and sufficient blood supply requires addressing social

attitudes and misconceptions about blood donation, especially in high-risk communities. Public health authorities can enhance blood donation, minimize HIV transmission, and ensure blood supply safety by considering these factors. Blood donation and HIV screening are challenging; thus this complete strategy is needed to protect public health and avoid transfusion-transmitted diseases[28].

Comparison of HIV Screening Methods in Blood Donors

Comparing blood donors HIV screening is difficult yet essential for international blood transfusion safety. Several HIV screening methods for donated blood have pros and downsides. Blood donations must be HIV-free for patient safety. Thus, HIV screening methods' efficacy, sensitivity, specificity, and practicality must be understood[21]. HIV screening often uses ELISA. ELISA methods identify HIV antibodies in blood samples due to their sensitivity and specificity. The test detects a signal from patient antibodies binding to solid-surface antigens. Since ELISA can detect low antibody levels, it is essential for early diagnosis. ELISA is too laborious and slow for high-throughput screening. Antibody tests may miss HIV early in infection if antibodies have not yet been produced.

Additionally, quick diagnostic testing is common. RDTs take minutes, ELISA hours. Simple tests require minimum lab equipment. RDTs are best for low-resource areas lacking modern labs. Compared to ELISA, faster and simpler procedures lose sensitivity and specificity. Cross-reactivity with other proteins can induce RDT false negatives and positives, especially early in infection when antibody levels are low. RDTs help promote HIV testing, especially in remote or impoverished areas, despite these limitations[5]. Nucleic acid testing (NAT) advances HIV screening. NAT identifies virus DNA, not antibodies. HIV can be detected before antibodies. With its sensitivity, NAT can substantially narrow the infection detection window. Transfusion-transmitted HIV risk has decreased with NAT. NAT requires expensive equipment and trained operators, restricting its application in low-resource situations. NAT is better for centralized labs than point-of-care testing due to complexity and cost.

CLIA uses immunoassay and chemiluminescence. Like ELISA, these assays are sensitive and selective but faster. CLIA assays measure light intensity using reactive chemicals to detect HIV antibodies. This method balances speed and accuracy for blood donor HIV screening. Clinical labs and blood banks employ CLIA to verify blood safety[29]. HIV screening methods are chosen based on demands and limits. RDTs work better in rural areas with limited resources, whereas CLIA is faster and more efficient at high-volume blood donation centers. NAT reduces the undiscovered infection window in centralized labs, improving safety[30]. Screening effectiveness depends on context. Screening can affect HIV-endemic transfusion-transmitted infection rates. NAT or CLIA's early infection detection may improve blood safety in high-prevalence areas. ELISA or CLIA's specificity is crucial in low-prevalence environments with higher false positives [31].

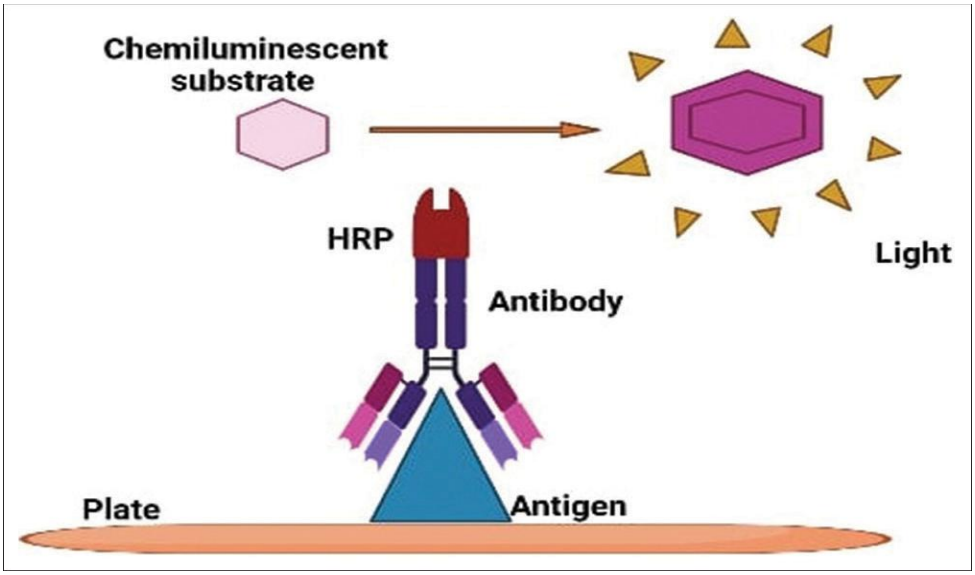

Figure 2. Principle of Chemiluminescence Immunoassay.

Training and proficiency of lab workers affect HIV screening accuracy. Pros perform and interpret tests accurately, reducing errors and delivering dependable results. HIV screening criteria demand ongoing training and quality assurance. Audits and standards help identify and fix screening process flaws[28]. HIV screening effectiveness and uptake depend on regulation. Blood donation clinics follow international and national laws. These guidelines require blood supply safety screening technologies to fulfill sensitivity and specificity levels. For public trust and screening program efficacy, regulations must be consistent and scientific. These criteria

must be updated often to reflect technological and epidemiological developments to maintain HIV testing relevant[32].

Public health plans must reflect regional socioeconomics. Well-funded HIV screening programs use NAT, while underfunded ones use RDTs. International alliances and global health organizations should train low-resource screening teams to close these gaps[33]. HIV screening programs may be affected by blood donors. HIV stigma and blood donation safety concerns can dissuade donors. Education and community participation are needed to overcome these challenges, promote safe donation, and boost blood donation. Public health communications should clarify falsehoods, eliminate stigma, and promote blood donation[34]. Rapid clinical and emergency turnaround times may affect HIV screening method choice. Though less sensitive, RDTs can save blood transfusions due to their rapidity. Many screening technologies are needed to promptly identify and eliminate infectious contributions to save lives.

Tech changes HIV screening. Innovative testing methodologies and affordable, user-friendly diagnostic equipment could improve HIV screening accuracy and accessibility. This topic requires ongoing research and development to overcome method limitations and create new blood supply safety and reliability methods[29]. HIV screening with different methods is more thorough. Blood donors can be tested using ELISA, RDT, NAT, and CLIA to balance their strengths and weaknesses. Tiering can improve early infection detection, reduce false positives and negatives, and protect the blood supply[35]. Comparing HIV screening methods in blood donors shows a complex combination of efficacy, sensitivity, specificity, and practicality. HIV screening benefits from ELISA's sensitivity and specificity, RDTs' speed and accessibility, NAT's early detection, and CLIA's efficiency. HIV prevalence, resources, restrictions, and setting dictate screening. HIV screening accuracy and dependability require continual training, quality assurance, and public health. New screening and testing methods will improve blood supply safety and reliability as technology advances. Public health officials must be alert, adaptable, and devoted to improving HIV screening for patient safety and public health[36]

Transfusion-transmitted HIV is deadly, thus accurate screening is essential. Trauma, surgery, and transfusion-dependent chronic disease patients are vulnerable. Healthcare providers prioritize safe blood for them. Selecting the right screening procedures is needed[37]. ELISA has long been the gold standard for HIV screening because to its sensitivity and specificity. Low HIV antibody detection in ELISA allows early diagnosis. An approach that relies on antibody development may miss recent infections without antibodies. ELISA is utilized at blood donation centers worldwide due to its lifespan and reliability, despite its limits. RDTs boost HIV screening in low-resource areas. Speed and simplicity make RDTs appropriate for point-of-care testing. These tests take minutes and require little expertise or equipment. Even while RDTs are less sensitive and specific than ELISA, they are easier to use in remote or resource-poor areas. Speed and precision must match the screening program's needs[38].

Nucleic acid testing improves HIV screening. To detect early infections, NAT identifies virus genetic material before antibodies are produced. Window time is reduced, and blood supply safety improved. NAT targets transfusion-transmitted HIV due to its sensitivity and specificity. Due to its expense and complexity, NAT is rarely used in low-resource scenarios. Centralized labs with infrastructure and qualified staff are preferable for NAT deployment[39]. CLIA balances speed, sensitivity, and specificity. The CLIA immunoassay with chemiluminescent detection offer accurate screening results. Speed and precision make CLIA ideal for high-volume blood donation venues. Blood banks and clinical laboratories use CLIA extensively, confirming its blood supply safety benefits[40]. Population HIV prevalence determines HIV screening efficacy. High-prevalence areas have more HIV-positive donors, necessitating better detection. Such situations benefit from NAT and CLIA's sensitivity. ELISA or CLIA's specificity may prevent false positives in low-prevalence conditions. The epidemiological context must be considered while choosing a safe and reliable screening procedure[41].

Laboratory staff training and proficiency affect HIV screening test accuracy and reliability. Staff must be well-trained and follow processes to reduce errors and maintain screening standards. Laboratory staff need continuous training and quality assurance to stay current on technologies and best practices. Process and protocol compliance are improved by audits and performance reviews[42]. Blood donor to ensure accuracy, HIV screening is controlled. Screenings must meet global and national sensitivity and specificity standards. These rules maintain blood supply safety and scientific screening. These rules must be updated often for technical and epidemiological changes. These limits must be implemented by public health groups to reestablish blood safety trust[43]. Public health must consider area socioeconomics. Well-funded HIV screening programs use NAT, while underfunded ones use RDTs. Global health groups and alliances can improve low-resource screening. Right HIV screening everywhere requires global health equality[44].

Culture, education, and public health messaging affect blood donation. Misconceptions about blood donation's safety and value may dissuade donors. Education and community engagement are needed to overcome these challenges and encourage safe donation. Public health communications should clarify falsehoods, eliminate stigma, and promote blood donation. Communicating with community leaders and influencers builds trust and provides facts[45]. Rapid clinical and emergency turnaround times may affect HIV screening method choice. RDTs are less sensitive than other technologies, but their quickness is crucial in blood transfusion emergencies.

Emergency detection and exclusion of infectious contributions saves lives. Screening options must vary by need and setting[46]. Tech changes HIV screening. Innovative testing methodologies and affordable, user-friendly diagnostic equipment could improve HIV screening accuracy and accessibility. This topic requires ongoing research and development to overcome method limitations and create new blood supply safety and reliability methods. Training and quality assurance help new technology succeed[47].

HIV testing is more complete with different approaches. Blood donors can be tested using ELISA, RDT, NAT, and CLIA to balance their strengths and weaknesses. Tiering can improve early infection detection, reduce false positives and negatives, and protect the blood supply. Planning and resource allocation are needed for screening process integration[48]. Comparing HIV screening methods in blood donors shows a complex combination of efficacy, sensitivity, specificity, and practicality. HIV screening benefits from ELISA's sensitivity and specificity, RDTs' speed and accessibility, NAT's early detection, and CLIA's efficiency. HIV prevalence, resources, restrictions, and setting dictate screening. HIV screening accuracy and dependability require continual training, quality assurance, and public health. New screening and testing methods will improve blood supply safety and reliability as technology advances. Public health officials must be alert, adaptable, and devoted to improving HIV screening for patient safety and public health. Comprehensive HIV screening is needed because transfusion-transmitted HIV is hazardous[4950].

Figure 3. Types of HIV Tests

The Current Situation of Human Immunodeficiency Virus (HIV) in Saudi Arabia

Saudi Arabia's HIV epidemic is affected by healthcare facilities, cultural attitudes, public health measures, and socioeconomic conditions. These factors must be explored to understand HIV in this region and identify prevention, diagnostic, and treatment challenges and opportunities[51] . HIV is still a major public health issue in Saudi Arabia, despite its lower prevalence. The country's conservative cultural and religious milieu, which strongly affects HIV/AIDS perception and reaction, contributes to this lower frequency. Stigma, public misunderstanding, and cultural sensitivity hamper HIV prevention and treatment, however rare [52].

Well-funded and contemporary, Saudi healthcare has considerable medical infrastructure and equipment. HIV care has improved under government. HIV/AIDS stigma still hinders progress. HIV-positive people are shunned, hindering testing and treatment. Stigma delays diagnosis of untreated infections, increasing morbidity and mortality[53]The Saudi Ministry of Health promotes HIV/AIDS awareness, prevention, and treatment. All Saudis with HIV receive free ART per national guidelines. These projects prevent HIV transmission and improve infected people's lives. Stigma and cultural barriers prevent people from adopting these programs, limiting their success[54].

Saudi Arabia's HIV population is mostly MSM, IDUs, and sex workers. Medical access is difficult for these communities due to societal and legal constraints. These people may be hidden by criminalization and stigma, making public health initiatives difficult. Therefore, these vital populations are more prone to contract and spread HIV[55]. Saudi Arabia's public health plan requires HIV testing and screening. Volunteer counseling and testing (VCT) clinics have grown, especially in cities. Fear of stigma and ignorance keep HIV testing low

despite these efforts. Because of the social stigma of a positive diagnosis, many forgo testing. Hesitation slows diagnosis, prevention, and treatment[56].

Education and public health measures are needed to reduce HIV stigma. HIV transmission, prevention, and early testing and treatment are promoted by Ministry of Health programs. These activities dispel HIV myths and reduce stigma. Change is gradual and difficult for core cultural beliefs[57]. Recently, targeted HIV medicines for high-risk patients have gained popularity. HIV prevention requires harm reduction for IDUs, safe sex for MSM, and sex worker support. These interventions work best when sensitive and culturally appropriate. Local expertise and trust can help NGOs and CBOs expand these projects[58].

ART accessibility has dramatically improved HIV prognoses in Saudi Arabia. Saudi nationals receive free ART, while non-nationals are being offered it. ART decreases viral load, lowering transmission risk and improving health. Despite advancements, stigma, fear of disclosure, and lack of social support make ART adherence challenging[59]. Research and surveillance are needed to understand Saudi HIV epidemiology and guide public health actions. Surveillance tracks HIV prevalence, risk factors, and therapeutic efficacy. Prevention and treatment programs are tailored to population requirements using surveillance data. By underreporting and hiding essential populations, surveillance data may be erroneous and incomplete[60].

HIV services should be integrated into healthcare activities to improve access. HIV testing and treatment in primary care reduces stigma and increases access. This approach manages HIV co-morbidities such TB and hepatitis. Integrating services boosts efficiency and health outcomes[61].

Global health groups and alliances help Saudi Arabia's HIV response. WHO and UNAIDS collaborations provide technical assistance, funding, and best practices. These relationships improve HIV prevention, diagnosis, and treatment and align with global goals (Ali et al., 2023). Cultural and religious variations in Saudi Arabia present HIV prevention challenges and opportunities. Religious leaders and institutions affect public opinion. Religious leaders in public health campaigns can build HIV support. HIV prevention and treatment can be presented within religion to reduce stigma and improve health[62]. Youth needs must be addressed in Saudi HIV prevention. HIV is more harmful for youth due to ignorance, risky behavior, and poor healthcare. Sexual education programs that teach HIV prevention, safe sex, and testing can help youth make health decisions. These activities should successfully engage youth culturally[20].

The role of technology and digital platforms in HIV prevention and treatment is expanding. MHealth activities like texting and mobile apps promote drug adherence. These technologies can reach many people and offer specific assistance. Digital platforms can make HIV testing and counseling anonymous, reducing stigma and disclosure anxieties[19].Also important is HIV's economic impact on individuals and society. HIV patients and their families may face high healthcare costs, lost productivity, and financial difficulty. Public health strategies that reduce HIV incidence and improve management can lower healthcare expenditures and improve HIV patients' lives. HIV prevention and treatment are economic and public health issues[63]. The Saudi social structure that determines public beliefs and health habits makes HIV prevention challenging. Religious and traditional values reinforce HIV/AIDS stigma and prejudice in public discourse. This climate might hamper public health initiatives because people fear social marginalization and legal consequences for immoral or illegal behavior. These concerns require culturally responsive public health strategies that reduce stigma and resonate with the population[18].

Saudi Arabia's HIV prevention plan promotes abstinence and faith, mirroring its religion. More extensive harm-reduction and risk-minimization methods are emerging. Policymakers and public health officials realize that HIV transmission's numerous components require a multifaceted approach. HIV prevention and health interventions require this paradigm shift[17]. Lack of HIV statistics in Saudi Arabia hinders pandemic battle. Due to the sensitive nature of HIV and fear of social and legal repercussions, many infections are unreported, hence surveillance figures may not accurately reflect the HIV epidemic. Effective public health strategies demand better data and reporting. This includes assisting healthcare providers in HIV detection and reporting, protecting confidentiality, and reducing disclosure anxiety[64].

Understanding HIV transmission dynamics in Saudi Arabia requires better data collecting and targeted research. Key demographic habits, risk variables, and social and structural HIV risk factors are examined. Saudi Arabia can tailor public health programs by studying successful interventions. Local and global expert cooperation can increase this research's quality and relevance[65] . Education and awareness are key to fighting HIV in Saudi Arabia. Properly created campaigns reach the target audience and are culturally relevant. Use culturally and religiously appropriate language and images and mobilize community leaders and influencers to promote HIV prevention and treatment. These activities can reduce stigma and promote testing and treatment by establishing a welcoming environment[4].

NGOs and CBOs are crucial to HIV prevention. Strong community ties allow these organizations to reach HIV-risk populations. NGOs and CBOs can help public health programs understand community needs and challenges. They can build trust and ensure culturally sensitive, effective interventions[22]. Recently, HIV services have become more important in healthcare. The approach reduces stigma and simplifies service access. Regular HIV testing and treatment can normalize these services and reduce patient anxiety. This integration can manage

HIV-related co-morbidities like tuberculosis and hepatitis. Integrating services boosts efficiency and health outcomes[23].

International organizations and donors are vital to Saudi Arabia's HIV response. UNAIDS and WHO provide funding, technical assistance, and best practices. These partnerships improve HIV prevention, diagnosis, and treatment in the country and align programs with global goals. Saudi Arabia can learn from other nations' successes and failures with international support[24]. HIV prevention in Saudi Arabia requires regional and international cooperation. MENA has HIV stigma, cultural sensitivities, and data shortages. Regional cooperation can share best practices and coordinate solutions. Collaboration can keep HIV on the public health agenda to improve advocacy[25].

Saudi Arabia fears HIV's economic impact. HIV can cause high healthcare costs, lost productivity, and financial hardship for patients and families. Public health interventions that lower HIV incidence and improve management can lower healthcare costs and improve HIV patients' lives. HIV prevention and treatment are economic and public health priorities. HIV reduction can boost Saudi health and economy[26] . Saudi HIV prevention must be multifaceted. This includes improving public health infrastructure, data collection and reporting, targeted research, and culturally sensitive education and awareness campaigns. NGOs, CBOs, and international organizations must work together to reach key populations and improve public health. HIV services can be integrated into healthcare and supported by international and regional partners to improve response[27].

Technology and digital platforms are increasingly used in HIV prevention and treatment. Text messaging and mobile apps can promote medication adherence. These tools can discreetly inform and support a large audience. Digital platforms can anonymize HIV testing and counseling, reducing stigma and disclosure fears. Technology can make HIV services more accessible and effective, especially for digital-savvy youth[28]. Saudi religious leaders and institutions must support HIV public health campaigns. Religious leaders can reduce stigma and promote healthy habits by influencing public opinion. Faith-based HIV prevention and treatment can support HIV-positive people and encourage testing and treatment. Public health awareness campaigns can benefit from religious leaders[33].

Youth needs must be addressed in Saudi HIV prevention. Youth are especially vulnerable to HIV due to ignorance, risk-taking, and lack of healthcare. Sexual education programs that teach HIV prevention, safe sex, and testing can help teens make health decisions. The programs should engage youth culturally and effectively. Saudi youth can understand and fight HIV through education and empowerment[34]. Cultural beliefs, healthcare infrastructure, and public health policies shape HIV in Saudi Arabia. Although HIV prevalence is low, stigma, data collection, and reaching key populations remain issues. A multifaceted approach is needed to reduce HIV prevalence and improve patient health. Increase public health infrastructure, conduct targeted research, and promote culturally sensitive education and awareness. NGOs, CBOs, international organizations, and religious leaders must work together to reach key populations and improve public health programs. Through international and regional partnerships and technological innovations, Saudi Arabia can fight HIV and improve population health[29].

HIV Infection among Blood Donors

Public health issues like HIV in blood donors require research and strategic interventions to ensure blood transfusion safety. Giving blood saves lives in healthcare. Screening and management are needed to prevent HIV-related transfusion-transmitted infections. Complex blood donor HIV epidemiology, screening, public health, and socioeconomic factors must be managed[59]. HIV rates among blood donors match population trends. Geography, socioeconomic status, and demographics affect donor HIV prevalence. High-HIV areas have more HIV-positive blood donations, requiring strict screening and testing. In low-HIV areas, focus may shift to reducing false positives while remaining vigilant. HIV prevalence depends on blood donors' age, gender, and sexuality. Understanding epidemiological factors helps develop targeted interventions and screening[60].

Multiple HIV screening methods for blood donors have pros and cons. ELISA is popular for its sensitivity and specificity. HIV-ELISA antibodies reliably detect infection. This method requires antibodies, which may not be present early in infection. HIV antibody detection window is difficult for ELISA. ELISA's robustness and reliability make it an HIV screening staple despite this limitation[66]. Rapid diagnostic tests (RDTs) can replace ELISA and provide results in minutes with minimal lab infrastructure. RDTs help low-resource labs without advanced equipment. Easy point-of-care testing with these tests. RDTs have lower sensitivity and specificity than ELISA, causing false positives and negatives. Especially in high-prevalence areas with high infection loss, speed and accuracy must be balanced[21].

The better HIV screening method is nucleic acid testing (NAT), which detects HIV genetic material instead of antibodies. NAT reduces the window, detecting HIV early. Blood supply safety is enhanced by the sensitive and specific method. Staff training and lab infrastructure are needed for NAT implementation. NAT's cost and complexity may limit its use in low-resource settings. Early infection detection makes HIV screening necessary[67]. Chemical luminescence immunoassays are sensitive, specific, and fast. Because of its reliability and

efficiency, clinical laboratories and blood banks use CLIA for HIV screening. CLIA is fast and accurate, so high-volume blood donation centers prefer it. Improved HIV detection by CLIA protects blood. Resource, HIV prevalence, and setting needs determine screening method. RDTs' simplicity and accessibility may appeal to low-resource settings, while NAT or CLIA's sensitivity may benefit high-prevalence areas. For completeness, multiple screening methods can balance strengths and weaknesses. This multilayered approach detects infections early, reduces false positives and negatives, and protects the blood supply[68].

Blood donor public health controls HIV. Donor education, high-risk population interventions, and strict screening are used. Risk disclosure and safe blood donation require donor education. Explain HIV transmission, testing, and diagnosis consequences in educational campaigns. Understanding and transparency can reduce HIV stigma and increase blood donation in these campaigns[18]. High-risk blood donors need targeted HIV prevention. Sex workers, MSM, and IDUs often contract and spread HIV. These groups need harm reduction, safe sex education, testing, and treatment from public health initiatives. These interventions can be enhanced by NGO/CBO partnerships. Our partnerships can engage high-risk populations with local knowledge and trust[69].

Blood supply safety requires strict screening. Professional standards from national and international health organizations must guide these protocols. Standardize donor screening, sample collection, and testing for reliability. These protocols ensure lab test results are accurate and reproducible. Quality control and audits ensure compliance and resolve issues[65].

Leadership and governance are needed for blood donation programs. Lab managers and supervisors guarantee quality, manage operations, and resolve issues quickly. Quality management systems must cover sample collection to result reporting in labs. Lab quality testing and improvement are organized by quality management systems[4]. External QA programs guarantee HIV screening quality. A third party distributes and analyzes proficiency testing samples to evaluate a lab's EQA. EQA programs objectively assess lab competence and are often required for accreditation. Labs improve and meet standards with EQA. Through insights, EQA programs improve testing[22]. Quality checks include laboratory accreditation. An independent body certifies labs' standards compliance. Laboratory accreditation requires quality and performance. Accreditation examines a laboratory's quality management system, personnel qualifications, testing protocols, and quality control. Accredited laboratories are committed to accurate testing[23].

To improve HIV screening, lab, healthcare, and public health staff must collaborate. Clear test results are essential for clinical decision-making and patient management. For proper patient care, doctors and labs must share test results. HIV trend surveillance and policymaking require public health authority cooperation[24]. HIV screening data management requires IT. LIMS simplify sample tracking, test result reporting, and quality control. EHRs and lab data are integrated to make test results easy to share with doctors. IT boosts data integrity, lab efficiency, and manual error reduction[25]. HIV screening integrity requires ethical lab practices. Labs must handle patient samples ethically, keep test results private, and get informed consent. Ethical obligations include patient and test result confidentiality. Patients consent to testing knowing its consequences. Ethics builds patient-provider and healthcare system trust[26].

Maintaining HIV screening requires quality improvement. Systematic analysis and targeted interventions improve quality. Process mapping, root cause analysis, and performance benchmarking help labs improve. Laboratory staff quality improvement activities promote quality culture and proactive problem-solving[27]. Patient feedback aids HIV screening. Laboratory patient satisfaction surveys and feedback suggest improvements. Testing process accessibility, timeliness, and result communication feedback inform quality improvement. Laboratory services are patient-centered with patient feedback[28]. Policy and regulation greatly affect HIV screening. Labs must follow national and international regulations for accurate test results. Quality assurance requires such regulations. Policymakers must establish and enforce high-quality testing standards. Promote evidence-based laws to give labs the resources and support they need to test well[32].

HIV screening quality and advancement require R&D. R&D develops testing technologies, methods, and quality assurance. Academic, research, and industry partners advance science. HIV testing and lab services improve with R&D[33]. Quality HIV screening requires international partnerships. Quality assurance is supported by WHO, UNAIDS, and the CDC with funding, expertise, and best practices. International partnerships share knowledge, resources, and expertise to grow low-resource labs. Global collaboration is needed for accurate HIV screening in all labs[34]. Laboratory workflows must include quality assurance to ensure HIV screening quality at all levels. All laboratory activities—from sample collection to result reporting—must be quality-controlled. Routine laboratory quality assurance requires clear staff roles and responsibilities. Laboratory workflows can include quality assurance for consistency and reliability[29].

Quality assurance practices must be monitored to maintain HIV screening standards. Laboatory monitoring includes quality, proficiency, and patient feedback. Evaluation examines quality assurance and suggests improvements. Continuous monitoring and evaluation help labs make data-driven decisions and improve quality with targeted interventions[35]. HIV screening quality assurance requires capacity building. Capacity building provides high-quality testing knowledge and resources. Improving infrastructure, training lab staff, and offering

advanced testing technologies are examples. Laboratory capacity building should be sustainable and customized. HIV screening accuracy improves with lab capacity[37].

Adequate HIV screening requires good leadership and governance. Leadership defines quality, sets QAI goals, and provides resources and support. Effective governance, procedures, and oversight ensure quality assurance. Good leadership and governance boost lab accountability, quality, and improvement[38]. Finally, blood donor HIV requires multifaceted treatment. Including strict screening, effective public health strategies, and HIV-related socioeconomic factors. Blood supply reliability requires advanced testing, continuous quality improvement, and stakeholder collaboration. These elements help healthcare systems reduce blood donor HIV risk, improve patient outcomes, and support public health goals[39].

CONCLUSION

The relationship between blood donation and the incidence of HIV is complex and multifaceted, requiring a comprehensive approach to ensure blood safety and public health. Advanced screening technologies, such as nucleic acid testing (NAT), have significantly improved the detection of HIV among blood donors, reducing the risk of transfusion-transmitted infections. However, challenges remain, particularly in low-resource settings where implementing and maintaining thorough screening methods can be difficult. Public health strategies must address demographic and socioeconomic factors, as well as social attitudes and misconceptions about HIV and blood donation, to enhance donor participation and ensure a safe blood supply. International collaboration and support are crucial in addressing disparities and promoting effective blood donation practices worldwide. Overall, a coordinated effort involving advanced screening, targeted public health interventions, and community engagement is essential to mitigate the risks associated with blood donation and HIV.

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