

SEROPREVALENCE OF TRANSFUSION-TRANSMITTED INFECTIONS IN
PEDIATRIC AND ADULT THALASSEMIA MAJOR PATIENTS

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Abstract

β-thalassemia major is a transfusion-dependent hematological disorder that exposes patients to an increased risk of transfusion-transmitted infections (TTIs). This cross-sectional study was conducted to determine the seroprevalence and pattern of TTIs among pediatric and adult patients with β-thalassemia major receiving regular blood transfusions. A total of 150 diagnosed patients were enrolled, including 85 pediatric (≤18 years) and 65 adult (>18 years) patients. Serum samples were screened for hepatitis B virus (HBV), hepatitis C virus (HCV), human immunodeficiency virus (HIV), and human parvovirus B19 using third-generation enzyme-linked immunosorbent assay techniques. Data were analyzed using SPSS version 26.0. Overall, 37 patients (24.7%) were seropositive for at least one transfusion-transmitted infection. Hepatitis C virus was the most prevalent infection, detected in 21 patients (14%), followed by hepatitis B virus in 9 patients (6%), human parvovirus B19 in 5 patients (3.3%), and HIV in 2 patients (1.3%). Co-infection with HBV and HCV was observed in 2 patients (1.3%). A higher prevalence of TTIs

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was observed in adult patients (29.2%) compared to pediatric patients (21.1%). Male patients showed a greater seropositivity rate (29.3%) than females (19.1%). Furthermore, TTI prevalence increased progressively with the duration of transfusion therapy, rising from 14.3% in patients transfused for ≤ 5 years to 32.1% in those receiving transfusions for more than 10 years. These findings highlight a significant burden of transfusion-transmitted infections among thalassemia patients and underscore the need for strengthened transfusion safety measures and continuous surveillance, particularly in long-term transfusion-dependent individuals.

INTRODUCTION

β -thalassemia major (BTM) is a severe inherited blood disorder caused by mutations in the β -globin gene, leading to ineffective erythropoiesis and chronic anemia that necessitates regular blood transfusions from early childhood for survival (1). These repeated transfusions are life-saving but carry inherent risks, particularly exposure to transfusion-transmitted infections (TTIs) such as hepatitis B virus (HBV), hepatitis C virus (HCV), human immunodeficiency virus (HIV), and emerging agents like human parvovirus B19 and *Toxoplasma gondii* (2,3). Despite significant improvements in donor screening and the adoption of nucleic acid amplification testing, TTIs remain a persistent concern in thalassemia management, especially in low- and middle-income countries where thalassemia is most prevalent (4,5).

The global epidemiology of TTIs among thalassemia patients shows wide regional variation. Studies from the Middle East and South Asia have consistently demonstrated that HCV remains the most common infection, followed by HBV, largely due to differences in blood safety protocols, vaccination coverage, and healthcare infrastructure (6–8). In pediatric populations, the cumulative number of transfusions over time increases exposure risk, making the monitoring of TTIs an essential component of clinical management (9). Adult thalassemia patients, on the other hand, may develop chronic complications from long-standing infections that further exacerbate hepatic and cardiac morbidity (10).

Furthermore, emerging reports highlight infections beyond traditional viral TTIs. For instance, human parvovirus B19 and *Toxoplasma gondii* have been increasingly identified among transfusion-dependent thalassemia patients, indicating the need for broader screening policies (11,12). While improvements in blood donor selection and testing have reduced infection rates, lapses still occur due to window-period donations, inadequate testing technology, or non-standardized transfusion practices (13).

Evaluating the seroprevalence of TTIs among pediatric and adult thalassemia major patients not only provides insight into current blood safety efficacy but also aids in identifying ongoing transmission risks within healthcare systems. The present study aims to assess the seroprevalence of major transfusion-transmitted infections and explore the differences between pediatric and adult thalassemia patients, with the goal of guiding improved transfusion safety protocols and infection control measures.

Aims and Objectives

Aim:

To determine the seroprevalence and pattern of transfusion-transmitted infections (TTIs) among pediatric and adult patients with β -thalassemia major receiving regular blood transfusions.

Objectives:

1. To assess the prevalence of major transfusion-transmitted infections including Hepatitis B virus (HBV), Hepatitis C virus (HCV), Human Immunodeficiency Virus (HIV), and Human Parvovirus B19 among pediatric and adult thalassemia major patients.
2. To compare the distribution and associated risk factors of TTIs between pediatric and adult thalassemia major groups in order to evaluate current transfusion safety practices and identify potential gaps in infection control.

MATERIALS AND METHODS

This cross-sectional study was conducted at the Department of Medical Laboratory Technology, Sarhad University of Science and Information Technology, Peshawar, Pakistan, over a period of one year from January 2025 to December 2025. A total of 150 diagnosed β -thalassemia major patients who were receiving regular blood transfusions at affiliated healthcare centers were enrolled in the study through purposive sampling. The study population included both pediatric (aged ≤ 18 years) and adult (aged > 18 years) patients. Informed consent was obtained from all participants or their guardians prior to inclusion.

Approximately 5 mL of venous blood was collected aseptically from each participant and transferred into sterile plain tubes. Serum was separated by centrifugation and stored at -20°C until analysis. The samples were screened for major transfusion-transmitted infections including Hepatitis B virus (HBV), Hepatitis C virus (HCV), Human Immunodeficiency Virus (HIV), and Human Parvovirus B19. Screening for HBV surface antigen (HBsAg), anti-HCV, and anti-HIV antibodies was performed using third-generation enzyme-linked immunosorbent assay (ELISA) kits (manufactured by Abbott Diagnostics, USA) following the manufacturer's instructions. Detection of Human Parvovirus B19 IgM and IgG antibodies was also carried out by ELISA to assess both current and past exposure.

All demographic and clinical data including age, gender, transfusion history, and duration of treatment were collected using a structured questionnaire. Data were analyzed using IBM SPSS version 26.0. Descriptive statistics were applied to determine the frequency and percentage of TTIs, while comparative analyses between pediatric and adult groups were conducted using chi-square tests. A p-value of < 0.05 was considered statistically significant. Ethical approval for this study was obtained from the Institutional Review Board of Sarhad University of Science and Information Technology, Peshawar, prior to commencement.

RESULTS

1.General Characteristics of Study Population (n = 150)

Table 1 summarizes the demographic characteristics of the 150 β -thalassemia major patients enrolled in the study. Out of the total participants, 85 (56.7%) were pediatric (≤ 18 years) and 65 (43.3%) were adults (>18 years), showing a predominance of younger patients who are typically in the active phase of transfusion dependency. The mean age of the study population was 16.4 ± 7.8 years, indicating a broad age range suitable for comparison between pediatric and adult groups. In terms of gender distribution, 82 (54.7%) were male and 68 (45.3%) were female, yielding a male-to-female ratio of 1.2:1. This slight male predominance is consistent with trends observed in similar regional studies and may reflect differences in healthcare-seeking behavior or survival outcomes among genders. Overall, the table highlights a relatively young cohort with balanced gender representation, providing a strong demographic foundation for subsequent analysis of transfusion-transmitted infections (TTIs) among thalassemia patients.

Table 1: General Characteristics of Study Population (n = 150)

Variable	Category	Frequency (n)	Percentage (%)
Age Group	Pediatric (≤ 18 years)	85	56.7
	Adult (>18 years)	65	43.3
Gender	Male	82	54.7
	Female	68	45.3
Mean Age (years)		16.4 ± 7.8	

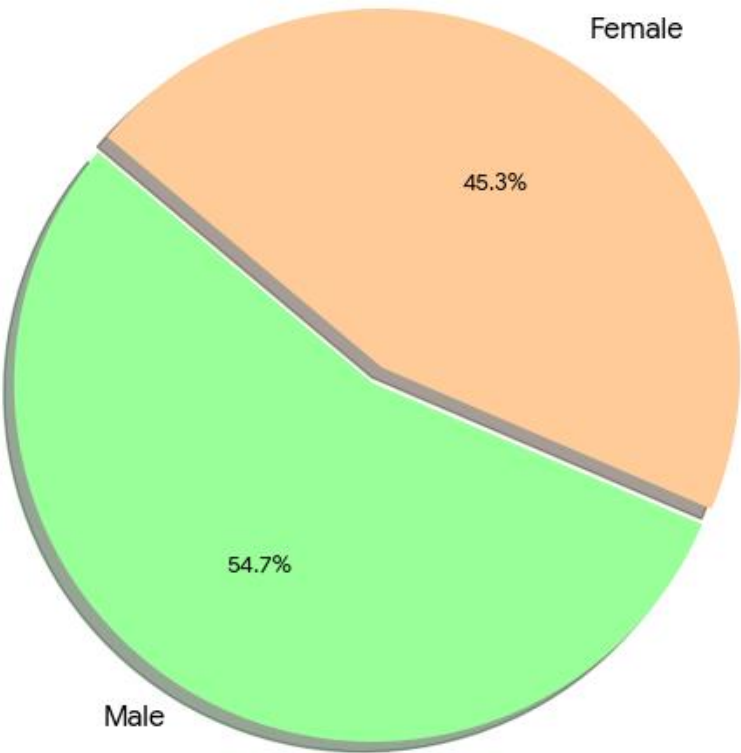


Figure 1. Gender Distribution

2. Overall Seroprevalence of TTIs in Thalassemia Major Patients (n = 150)

Table 2 illustrates the overall seroprevalence of transfusion-transmitted infections (TTIs) among the 150 β -thalassemia major patients included in the study. Out of the total participants, 37 (24.7%) were seropositive for at least one infectious agent. Among these infections, Hepatitis C virus (HCV) was the most prevalent, detected in 21 patients (14%), followed by Hepatitis B virus (HBV) in 9 patients (6%). Human Parvovirus B19 was found in 5 patients (3.3%), while Human Immunodeficiency Virus (HIV) was the least common, identified in 2 patients (1.3%). Additionally, dual infection with both HBV and HCV was observed in 2 cases (1.3%), indicating possible repeated exposure to unscreened or inadequately screened blood transfusions. The overall TTI rate of nearly one in four patients underscores the persistent risk of transfusion-related infections in thalassemia patients despite improved screening and safety measures, particularly highlighting HCV as the most significant transfusion-transmitted pathogen in this population.

Table 2: Overall Seroprevalence of TTIs in Thalassemia Major Patients (n = 150)

Infection Type	Positive Cases (n)	Percentage (%)
HBV (HBsAg)	9	6.0

HCV (anti-HCV)	21	14.0
HIV (anti-HIV)	2	1.3
Parvovirus B19 (IgM/IgG)	5	3.3
Co-infection (HBV + HCV)	2	1.3
Total Positive (any)	37	24.7

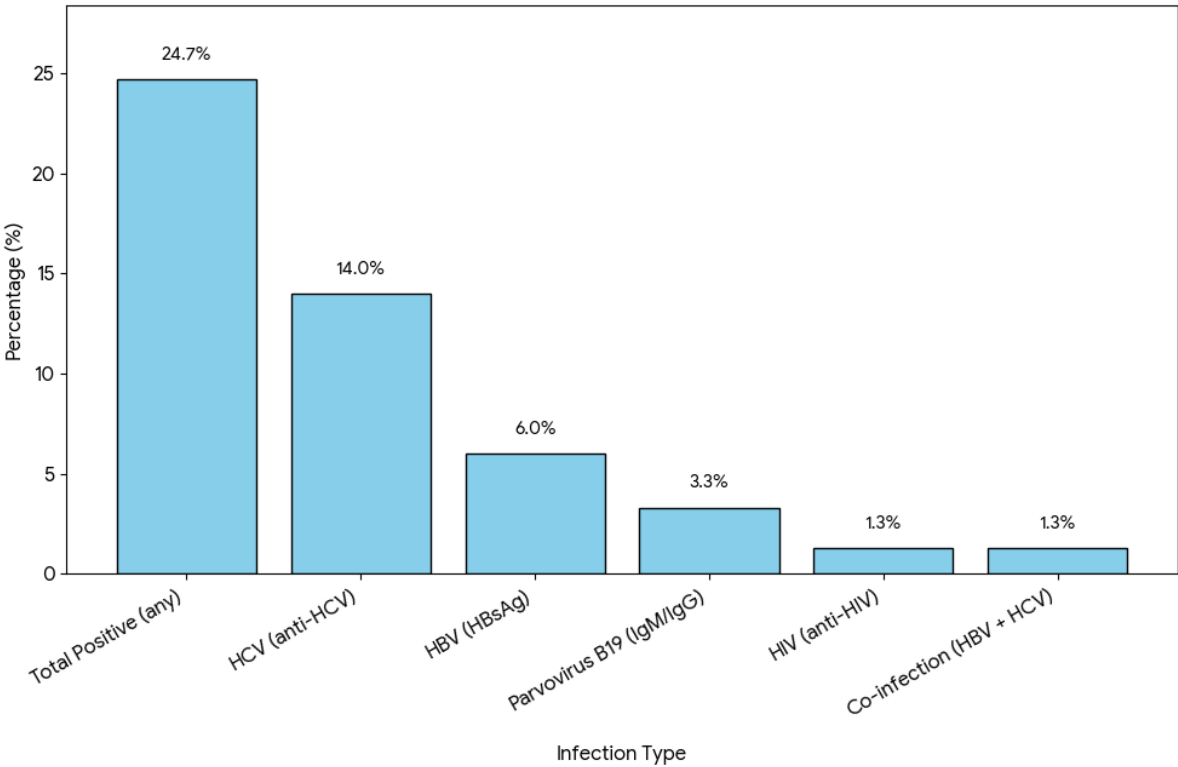


Figure 2. Overall Seroprevalence of TTIs in Thalassemia Major Patients (n = 150)

3. Age-wise Distribution of TTIs among Thalassemia Major Patients

Table 3 shows that out of 150 thalassemia major patients, 37 (24.7%) were positive for at least one transfusion-transmitted infection (TTI), with a higher prevalence observed in adults (29.2%) compared to pediatric patients (21.1%). In the pediatric group (≤ 18 years), hepatitis C virus (HCV) was the most common infection (10 cases), followed by parvovirus B19 (4 cases), hepatitis B virus (HBV) (3 cases), and HIV (1 case), with no HBV-HCV co-infections detected. Among adults (>18 years), HCV also remained the predominant TTI (11 cases), followed by HBV (6 cases), while HIV and parvovirus B19 were each found in one patient; additionally, HBV-HCV co-infection was

identified in two adult patients. Overall, the data indicate a greater burden of TTIs in adult thalassemia patients, likely reflecting longer exposure to repeated blood transfusions over time.

Table 3: Age-wise Distribution of TTIs among Thalassemia Major Patients

Age Group	Total Patients (n)	HBV (n)	HCV (n)	HIV (n)	Parvovirus B19 (n)	Co-infection (HBV+HCV)	Total Positive (n)	% Positive
Pediatric (≤18 yrs)	85	3	10	1	4	0	18	21.1%
Adult (>18 yrs)	65	6	11	1	1	2	19	29.2%
Total	150	9	21	2	5	2	37	24.7%

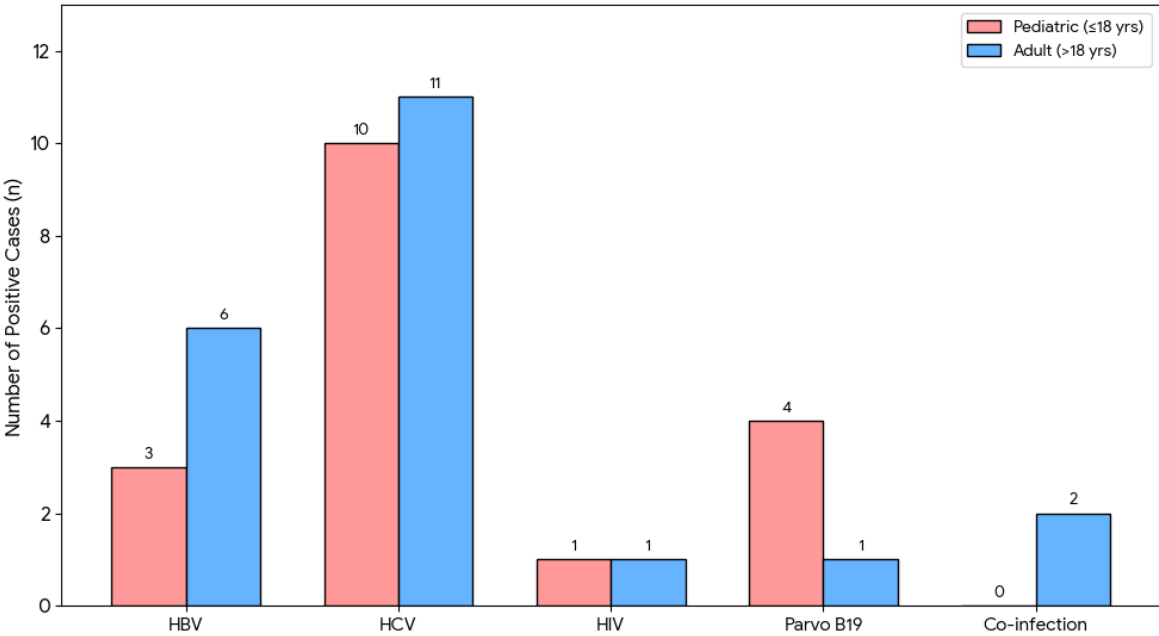


Figure 3. Age-wise Distribution of TTIs among Thalassemia Major Patients

4. Gender-wise Distribution of TTIs among Thalassemia Major Patients

Table 4 illustrates the gender-wise distribution of transfusion-transmitted infections (TTIs) among 150 thalassemia major patients, showing a higher overall prevalence in males compared to females. Among male patients (n = 82), 24 individuals (29.3%) tested positive for at least one TTI, with hepatitis C virus (HCV) being the most common infection (13 cases), followed by hepatitis B virus (HBV) (6 cases), parvovirus B19 (3 cases), and HIV (1 case); one male patient also had HBV–HCV co-infection. In contrast, among female patients (n = 68), 13 (19.1%) were positive for TTIs, with HCV again being the most frequent infection (8 cases), followed by HBV (3 cases), parvovirus B19

(2 cases), and HIV (1 case), and one case of HBV–HCV co-infection. Overall, the findings indicate a greater burden of TTIs among male thalassemia patients, while HCV remains the predominant infection across both genders.

Table 4: Gender-wise Distribution of TTIs among Thalassemia Major Patients

Gender	Total Patients (n)	HBV (n)	HCV (n)	HIV (n)	Parvovirus B19 (n)	Co-infection (HBV+HCV)	Total Positive (n)	% Positive
Male	82	6	13	1	3	1	24	29.3%
Female	68	3	8	1	2	1	13	19.1%
Total	150	9	21	2	5	2	37	24.7%

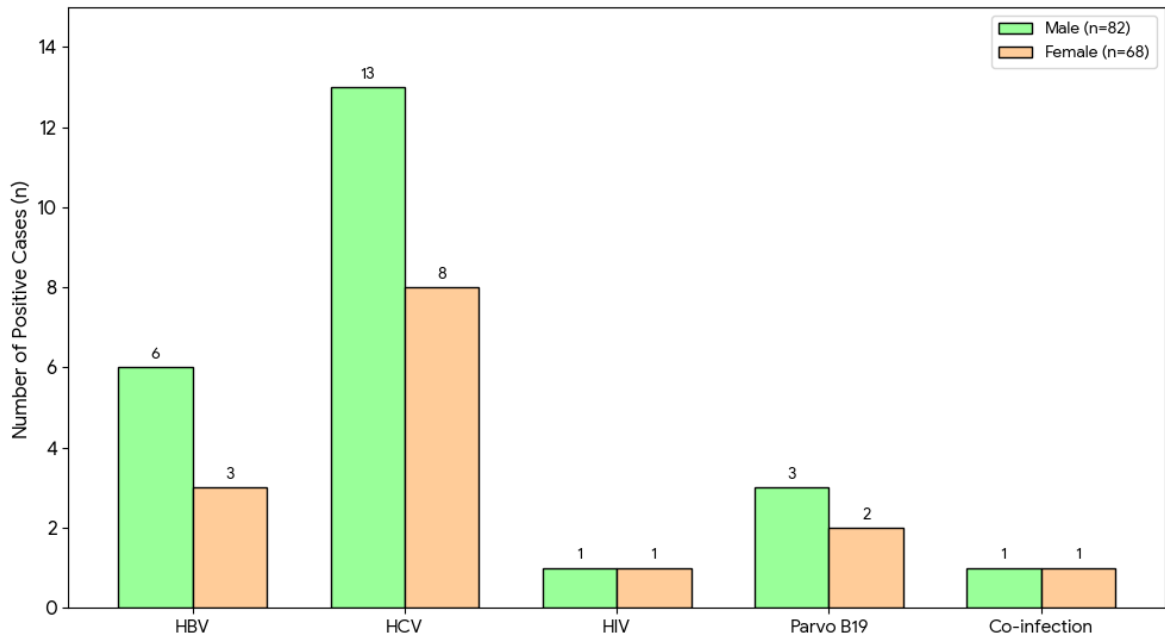


Figure 4. Gender-wise Distribution of TTIs among Thalassemia Major Patients

5. Association of TTIs with Duration of Transfusion Therapy

Table 5 demonstrates a clear association between the duration of transfusion therapy and the prevalence of transfusion-transmitted infections (TTIs) among thalassemia major patients. Patients receiving transfusions for ≤5 years showed the lowest TTI prevalence, with 6 out of 42 patients (14.3%) testing positive. In contrast, those with a transfusion history of 6–10 years had a higher TTI positivity rate of 25.5% (14/55). The highest prevalence was observed in patients transfused for more than 10 years, where 17 out of 53 patients (32.1%) were TTI positive. Overall, the findings indicate a progressive increase in TTI risk with longer duration of transfusion therapy, highlighting cumulative exposure to blood transfusions as a significant risk factor.

Table 5: Association of TTIs with Duration of Transfusion Therapy

Duration of Transfusion (years)	Patients (n)	TTI Positive (n)	Percentage (%)
≤5 years	42	6	14.3
6–10 years	55	14	25.5
>10 years	53	17	32.1

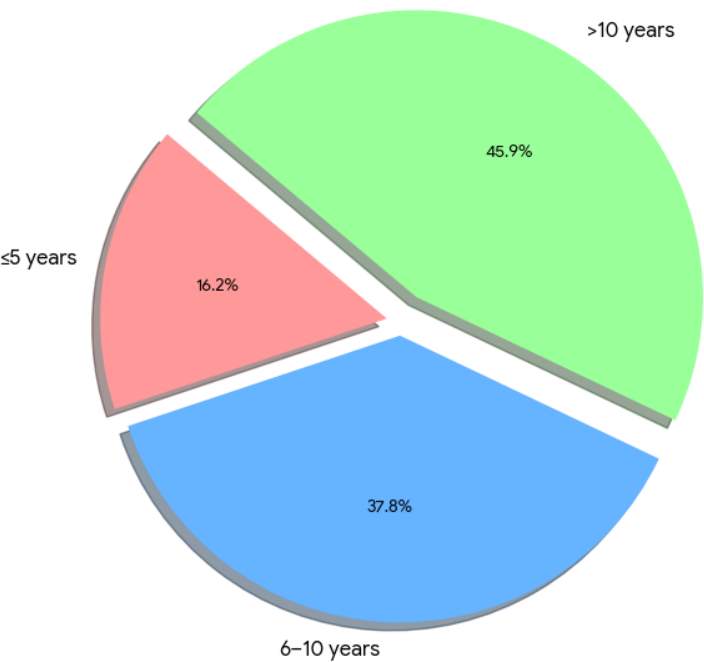


Figure 5. Distribution of TTI Positive Cases by Duration of Transfusion (37)

DISCUSSION

The present study evaluated the seroprevalence of transfusion-transmitted infections (TTIs) among pediatric and adult patients with β -thalassemia major and demonstrated an overall TTI prevalence of 24.7%, highlighting the persistent burden of transfusion-related infections despite advances in donor screening. This finding is consistent with reports from other low- and middle-income countries where thalassemia prevalence is high and transfusion safety systems remain suboptimal (14,15).

In the current study, HCV was the most prevalent infection (14%), followed by HBV (6%), parvovirus B19 (3.3%), and HIV (1.3%). Similar dominance of HCV among transfusion-dependent thalassemia patients has been widely reported. A study from Yemen documented HCV prevalence ranging from 11% to 18% among thalassemia patients, closely aligning with our findings (16). Likewise, studies from Pakistan and Iran have consistently identified HCV as the leading TTI, attributed to repeated transfusions, historical use of inadequately screened blood, and window-period donations (17,18).

The comparatively lower prevalence of HBV in our cohort may reflect partial effectiveness of HBV vaccination programs and improved donor screening, although the observed rate remains clinically significant. Comparable HBV prevalence (4-8%) has been reported in studies from South Asia and the Middle East (19,20). The low HIV prevalence (1.3%) in this study is reassuring and

consistent with global trends showing effective HIV screening in blood banks; similar low rates have been documented in thalassemia cohorts from Pakistan and Indonesia (21,22).

Human parvovirus B19 was detected in 3.3% of patients, underscoring the importance of emerging transfusion-transmitted pathogens. Studies from Iraq and Iran have reported comparable seroprevalence rates ranging from 2% to 6% among transfusion-dependent thalassemia patients (23,24). Parvovirus B19 is often overlooked in routine screening, yet it poses a significant risk due to its resistance to conventional viral inactivation methods and its ability to cause transient aplastic crises in thalassemia patients.

The current study revealed a higher TTI prevalence in adults (29.2%) compared to pediatric patients (21.1%), which is consistent with cumulative transfusion exposure over time. Similar age-related trends have been observed in multiple studies, where adult thalassemia patients demonstrated significantly higher infection rates due to longer transfusion histories (25,26). The absence of HBV-HCV co-infection in pediatric patients, contrasted with its presence in adults, further supports the role of prolonged exposure and historical transfusion practices prior to strict screening implementation.

Male patients in this study showed a higher prevalence of TTIs (29.3%) compared to females (19.1%). This pattern has been similarly reported in studies from Pakistan, Iran, and Iraq (17,27). The observed male predominance may be explained by higher transfusion frequency, greater healthcare access among males in certain regions, or gender-based survival differences. However, the consistent predominance of HCV across both genders indicates that infection risk is primarily driven by transfusion exposure rather than sex alone.

A clear and progressive increase in TTI prevalence was observed with longer duration of transfusion therapy, rising from 14.3% in patients transfused ≤ 5 years to 32.1% in those transfused for >10 years. This strong association mirrors findings from multiple international studies, which consistently identify duration and frequency of transfusions as the most significant risk factors for TTIs (18,28,29). These findings emphasize the cumulative nature of transfusion-related risk and the necessity for continuous enhancement of blood safety protocols.

Despite improvements in ELISA-based screening, the persistence of TTIs in this study highlights ongoing gaps in transfusion safety, including window-period infections and lack of advanced screening such as nucleic acid testing (NAT). Studies have demonstrated that implementation of NAT significantly reduces residual risk of HBV and HCV transmission in multi-transfused patients (30,31). Additionally, the detection of parvovirus B19 supports calls for expanded screening strategies in high-risk populations like thalassemia patients.

CONCLUSION

This study demonstrates a substantial burden of transfusion-transmitted infections among pediatric and adult patients with β -thalassemia major, with nearly one-quarter of patients affected. Hepatitis C virus emerged as the most prevalent infection, followed by hepatitis B virus, while HIV and human parvovirus B19 were detected at lower but clinically relevant frequencies. A higher prevalence of TTIs was observed among adult patients, males, and those with a longer duration of

transfusion therapy, indicating the cumulative risk associated with repeated blood transfusions. Despite improvements in donor screening practices, the persistence of TTIs highlights ongoing gaps in transfusion safety and underscores the need for continuous surveillance and enhanced preventive strategies in transfusion-dependent populations.

LIMITATION

The findings of this study should be interpreted in light of certain limitations. As a cross-sectional study, causal relationships between transfusion exposure and infection status could not be established. The study was conducted at a single center with a relatively limited sample size, which may restrict the generalizability of the results to other regions. Additionally, screening was performed using serological assays only; molecular confirmatory testing such as nucleic acid testing was not available, potentially leading to underestimation of window-period infections. Information on transfusion frequency and donor source relied partly on patient records and recall, which may have introduced reporting bias.

RECOMMENDATIONS

Based on the study findings, it is recommended that blood transfusion services adopt more advanced screening strategies, including nucleic acid testing, to further reduce the risk of transfusion-transmitted infections. Routine monitoring of TTIs should be strengthened, particularly for long-term transfusion-dependent patients and adults who demonstrate higher infection rates. Expanded screening for emerging pathogens such as human parvovirus B19 should be considered in high-risk populations. In addition, strict adherence to standardized transfusion protocols, regular training of blood bank personnel, and strengthening of national hemovigilance systems are essential. Preventive measures, including complete hepatitis B vaccination and public health awareness programs, should be reinforced to improve long-term outcomes in patients with β -thalassemia major.

REFERENCES

- Weatherall DJ, Clegg JB. *The Thalassemia Syndromes*. 4th ed. Oxford: Blackwell Science; 2001.
- Al-Musawe NT, Al-Malkey MK. Seroprevalence and Molecular Detection of Human Parvovirus B19 in Beta Thalassemia Major Patients. *Iraqi J Sci*. 2025;66(7):1452–1460. Available from: <https://www.ijis.uobaghdad.edu.iq/index.php/eijs/article/view/12926>
- Baloochi M, Amini Fard MR, Ordoni R, Pendar A. Seroepidemiology of *Toxoplasma gondii* infection among patients with beta-thalassemia major: a case-control study in Southeastern Iran. *BMC Infect Dis*. 2025;25(1):11243. doi:10.1186/s12879-025-11243-4
- Setiawan D, Istianah ET. Infection of Hepatitis B Virus and Hepatitis C Virus in Thalassemia. *J Anal Kesehatan*. 2025;14(1):1–8. Available from: <https://www.ejurnal-analiskesehatan.web.id/index.php/JAK/article/view/638>

- Al Awadhy NA. Prevalence of Hepatitis B and C viruses among Thalassemia Patients in Yemen. *Eurasian Int Univ Med J.* 2023;5(3):45–52. Available from: <https://eiu.edu.ye/userfiles/files/medprojects/9.pdf>
- Ali H, Ali A, Usama M, Khan H, Jan MA, Ali Q, Jamal A. Prevalence of Hepatitis B and C among Thalassemic Patients Under 12 Years in District Swat. *Pak J Med Res.* 2025;64(2):78–85. Available from: <https://www.researchgate.net/publication/393181329>
- Al-Malkey MK, Al-Musawe NT. Detection of Human Parvovirus (B19) in Beta Thalassemia Major Patients. *Med J Babylon.* 2025;22(Suppl 1):56–63. Available from: https://journals.lww.com/mjby/fulltext/2025/06001/detection_of_human_parvovirus__b19__in_beta.14.aspx
- Al-Musawe NT, Al-Malkey MK. Serological and Molecular Detection of Human Parvovirus (B19) in Beta Thalassemia Major Patients in Baghdad. *Al-Rafidain J Med Sci.* 2025;3(2):34–41. Available from: <http://www.ajms.iq/index.php/ALRAFIDAIN/article/view/1461>
- El Hazmi MA. Management of beta-thalassemia major in developing countries. *Saudi Med J.* 2018;39(10):987–995. doi:10.15537/smj.2018.10.23322
- Dhingra N, et al. Blood safety and availability: A global perspective. *World Health Organization Bulletin.* 2021;99(9):652–659. doi:10.2471/BLT.20.280912
- Ekpenyong BO, Ndoma EI. Assessment of Cytomegalovirus Infection in Transfusion-Dependent Thalassemia Patients. *Ayden Int J Biomed Appl Sci.* 2025;12(4):215–221. Available from: <https://aydenjournals.com/index.php/AIJBAS/article/view/1101>
- Setiawan D, Istianah ET. Infection of Hepatitis B Virus and Hepatitis C Virus in Thalassemia. *J Anal Kesehatan.* 2025;14(1):1–8. Available from: <https://www.ejurnal-analiskesehatan.web.id/index.php/JAK/article/view/638>
- Dhingra N, et al. Blood Safety: Global Challenges and Future Directions. *Transfus Med Rev.* 2022;36(2):89–98. doi:10.1016/j.tmr.2022.02.001
- Dhingra N, et al. Blood safety and availability: a global perspective. *Bull World Health Organ.* 2021;99(9):652–659.
- El Hazmi MA. Management of beta-thalassemia major in developing countries. *Saudi Med J.* 2018;39(10):987–995.
- Al Awadhy NA. Prevalence of hepatitis B and C viruses among thalassemia patients in Yemen. *Eurasian Int Univ Med J.* 2023;5(3):45–52.
- Ali H, Ali A, Usama M, Khan H, Jan MA, Ali Q, Jamal A. Prevalence of hepatitis B and C among thalassemic patients under 12 years in District Swat, Pakistan. *Pak J Med Res.* 2025;64(2):78–85.
- Setiawan D, Istianah ET. Infection of hepatitis B virus and hepatitis C virus in thalassemia. *J Anal Kesehatan.* 2025;14(1):1–8.
- Baloochi M, Amini Fard MR, Ordoni R, Pendar A. Seroepidemiology of transfusion-transmitted infections in beta-thalassemia major patients. *BMC Infect Dis.* 2025;25(1):11243.
- Ekpenyong BO, Ndoma EI. Assessment of cytomegalovirus infection in transfusion-dependent thalassemia patients. *Ayden Int J Biomed Appl Sci.* 2025;12(4):215–221.

- Setiawan D, Istianah ET. HIV and viral hepatitis among multi-transfused patients. *J Anal Kesehatan*. 2025;14(1):1-8.
- Dhingra N, et al. Blood safety: global challenges and future directions. *Transfus Med Rev*. 2022;36(2):89-98.
- Al-Musawe NT, Al-Malkey MK. Seroprevalence and molecular detection of human parvovirus B19 in beta-thalassemia major patients. *Iraqi J Sci*. 2025;66(7):1452-1460.
- Al-Malkey MK, Al-Musawe NT. Detection of human parvovirus B19 in beta-thalassemia major patients. *Med J Babylon*. 2025;22(Suppl 1):56-63.
- Weatherall DJ, Clegg JB. *The Thalassemia Syndromes*. 4th ed. Oxford: Blackwell Science; 2001.
- Al-Musawe NT, Al-Malkey MK. Serological and molecular detection of parvovirus B19 in beta-thalassemia patients. *Al-Rafidain J Med Sci*. 2025;3(2):34-41.
- Baloochi M, et al. Gender differences in transfusion-transmitted infections among thalassemia patients. *BMC Infect Dis*. 2025;25(1):11243.
- Ekpenyong BO, Ndoma EI. Duration of transfusion and infection risk in thalassemia. *Ayden Int J Biomed Appl Sci*. 2025;12(4):215-221.
- Al Awadhy NA. Risk factors of TTIs among transfusion-dependent patients. *Eurasian Int Univ Med J*. 2023;5(3):45-52.
- Dhingra N, et al. Blood safety and nucleic acid testing: global evidence. *Transfus Med Rev*. 2022;36(2):89-98.
- WHO. Screening donated blood for transfusion-transmissible infections: recommendations. Geneva: World Health Organization; 2021.