


# Viral infections after hematopoietic stem cell transplantation in children with acute lymphoblastic leukemia: the Polish experience

Anna Izabela Fałkowska<sup>1,2\*</sup> , Agnieszka Zaucha-Prażmo<sup>1</sup>, Katarzyna Drabko<sup>1</sup>, Krzysztof Czyżewski<sup>3</sup>, Oliwia Grochowska<sup>3</sup>, Kamila Jaremek<sup>3</sup>, Agnieszka Majk<sup>3</sup>, Patrycja Zalas-Więcek<sup>4</sup>, Jowita Frąckiewicz<sup>5</sup>, Małgorzata Salomonowicz-Bodzioch<sup>5</sup>, Marek Ussowicz<sup>5</sup>, Krzysztof Kałwak<sup>5</sup>, Liliana Chelmecka-Wiktorczyk<sup>6</sup>, Jolanta Goździk<sup>6</sup>, Jan Styczyński<sup>3</sup>, Jacek Wachowiak<sup>7</sup>, Olga Zając-Spychała<sup>7</sup>

<sup>1</sup>Department of Pediatric Hematology, Oncology and Transplantology, Medical University of Lublin, Lublin, Poland

<sup>2</sup>Children's University Hospital of Lublin, Lublin, Poland

<sup>3</sup>Department of Pediatric Hematology and Oncology, *Collegium Medicum*, Nicolaus Copernicus University in Toruń, Jurasz University Hospital 1, Bydgoszcz, Poland

<sup>4</sup>Department of Microbiology, *Collegium Medicum*, Nicolaus Copernicus University in Toruń, Jurasz University Hospital 1, Bydgoszcz, Poland

<sup>5</sup>Department of Pediatric Bone Marrow Transplantation, Oncology and Hematology, Wrocław Medical University, Wrocław, Poland

<sup>6</sup>Department of Pediatric Oncology and Hematology, Institute of Pediatrics, Jagiellonian University Medical College, Kraków, Poland

<sup>7</sup>Department of Pediatric Oncology, Hematology and Transplantology, Poznan University of Medical Sciences, Poznań, Poland

## Abstract

**Introduction:** Allogeneic hematopoietic stem cell transplantation (allo-HSCT) is one of the therapeutic options in pediatric acute lymphoblastic leukemia (ALL). Most previous analyses have concerned the reactivation of viruses in the entire population of children after allo-HSCT, regardless of the disease entity being an indication for transplantation. In our report, we aimed to evaluate the occurrence, etiology, risk factors and clinical outcome of viral infections in pediatric patients with ALL.

**Material and methods:** 83 post-HSCT ALL patients from 2020 through 2021 were analyzed for infections with polioma BK virus (BKV), cytomegalovirus (CMV), Epstein-Barr virus, severe acute respiratory syndrome coronavirus 2, adenovirus, respiratory syncytial virus, norovirus, rotavirus, influenza, human herpes virus-6, parainfluenza and rhinovirus.

**Results:** Viral infections were detected after 41% of the transplantations. The viruses most commonly detected were BKV (26.2%) and CMV (23.8%). The analyzed potential risk factors for viral infections were total body irradiation (TBI), graft-versus-host disease, complete remission status, and donor type. Overall survival in the investigated group was 0.815.

\*Address for correspondence: Anna Izabela Falkowska, Department of Pediatric Hematology, Oncology and Transplantology, Medical University of Lublin, Al. Raclawickie 1, 20–059 Lublin, Poland, e-mail: [annaizabelafalkowska@gmail.com](mailto:annaizabelafalkowska@gmail.com)

Received: 25.04.2023 Accepted: 19.06.2023 Early publication date: 19.07.2023

This article is available in open access under Creative Common Attribution-Non-Commercial-No Derivatives 4.0 International (CC BY-NC-ND 4.0) license, allowing to download articles and share them with others as long as they credit the authors and the publisher, but without permission to change them in any way or use them commercially.

**Conclusions:** Complications occurred more frequently in patients without TBI and we did not confirm the impact of other factors. Viral infections in children with ALL after allo-HSCT remain a significant problem. Our results highlight the importance of frequent monitoring and anti-viral prophylaxis.

**Key words:** hematopoietic stem cell transplantation, viral infections, pediatric ALL, post-transplant infectious complications

Acta Haematologica Polonica 2023; 54, 4: 221–226

## Introduction

Allogeneic hematopoietic stem cell transplantation (allo-HSCT) is one of the therapeutic options in pediatric acute lymphoblastic leukemia (ALL). Severe myelo- and lymphoablation, delayed immunoreconstitution, and the need for enhanced immunosuppression in the case of graft-versus-host disease (GvHD), all promote opportunistic infections, including viral infections [1–5].

Such complications result in longer immune recovery, intensive antiviral treatment, and longer hospitalization. Viremia post-HSCT is usually caused by virus reactivation of cytomegalovirus (CMV), Epstein-Barr virus (EBV), adenovirus (ADV), BK Polyomavirus (BKV), herpes simplex virus-1, -2 (HSV-1, HSV-2), varicella zoster virus (VZV), and human herpes virus-6, -7 (HHV-6, HHV-7) [4, 6–8].

This experience has led to frequent viral load monitoring and the use of prophylactic acyclovir for HSV, preemptive rituximab for EBV, and preemptive therapy for CMV [1, 9, 10].

The aim of this multi-center retrospective analysis was to characterize the frequency, type, risk factors and outcome of viral infections after HSCT in children with ALL.

## Material and methods

In this retrospective cohort study, the clinical records and medical charts of 83 children (aged 0.5–17.5 years) diagnosed with ALL who underwent allo-HSCT in five pediatric transplantation centers from 2020 through 2021 were analyzed. The mean age on the day of the stem cell infusion was  $8.7 \pm 4.4$  years. The disease status was first complete remission (CR1) in 74.7%, 24.1% of the patients received transplant in >CR1, and 1.2% were qualified as partial responders. For 16.9%, a matched family donor (MSD) was available. Most patients (72.3%) underwent HSCT from human leukocyte antigen (HLA)-identical unrelated donors [matched unrelated donor (MUD)] and 6.0% from mismatched unrelated donors (MMUD,  $\leq 9/10$ ). For 3.6% of the patients, the donor was a haploidentical family member. All patients received a myeloablative conditioning regimen, and in 56 patients (67.5%) the conditioning was based on total body irradiation (TBI).

**Table I.** Patients' general characteristics

Variable	N	% of all patients
Number of patients with ALL	83	
Age at HSCT, years, average $\pm$ SD	83	8.69 $\pm$ 4.35 Range: 0.57–17.62
Sex		
Female	37	44.6
Male	46	55.4
Donor type		
MMFD	3	3.6
MMUD	5	6.0
MSD	15	18.1
MUD	60	72.3
Remission status		
>CR1	20	24.1
CR1	62	74.7
PR	1	1.2
Conditioning regimen		
TBI-based	56	67.5
Non-TBI	27	32.5
Deaths	11	13.3
Deaths from infection	4	4.8

ALL – acute lymphoblastic leukemia; HSCT – hematopoietic stem cell transplantation; SD – standard deviation; MMFD – mismatched family donor; MMUD – mismatched unrelated donor; MSD – matched sibling donor; MUD – matched unrelated donor; CR1 – first complete remission; PR – partial remission; TBI – total body irradiation

The general characteristics of the analyzed patients are set out in Table I.

The analysis was performed in the R statistical package, version 4.0.5. Nominal variables are presented as the number of patients or the number of infections with % frequency. Quantitative variables are presented as mean  $\pm$  standard deviation (SD) or as median (first quartile; third quartile) with range. The survival rate was calculated taking into account the 95% confidence level [confidence interval (CI)], and Kaplan-Meier survival curves were determined.

## Results

The number of viral infections in the analyzed cohort was 83 diagnosed across 34 patients. The average age was 8.47 years (SD  $\pm$  4.78) and the group consisted of 13 girls and 21 boys. Among the children with viremia, 50% received TBI. In 82.4%, transplantation from MUD was performed, while MMUD, MSD and haploidentical donor transplant were performed in 5.9% of each. Out of five fatal cases, three (8.8%) were caused by an infectious complication. The diagnostic material was mostly blood plasma (50.6%), followed by nasal swab, urine, and feces (22.9%, 18.1%, and 8.4%, respectively). The characteristics of patients with viral infections are set out in Table II.

In the analyzed group, 44.6% of the patients received specific antiviral agents, and 25.3% required symptomatic treatment only. Complications occurred from day +4 to day +85 from transplantation (median 28 days). In 18.8% of the cases, GvHD preceded the occurrence of a viral infection.

The most commonly detected virus was BKV (26.2%). The etiology included also CMV (23.8%), while the third most common cause was severe acute respiratory syndrome novel coronavirus 2 (SARS-CoV-2 – 11.9%). Other detected pathogens were EBV (10.7%), ADV (8.3%), respiratory syncytial virus (RSV), norovirus, rotavirus, influenza, HHV-6, parainfluenza, and rhinovirus (see Table III).

The overall survival (regardless of cause of death) was 0.815 (95% CI: 0.715–0.928). When considering only deaths due to infection, this was 0.947 (95% CI: 0.898–0.999) (see Figure 1).

Viral pathogens were detected twice as frequently in the group without TBI (63%) than in the group with TBI (30.4%). The difference between the groups was statistically significant ( $p = 0.010$ ). In the non-TBI group, conditioning was based mostly on treosulfan (32.4%), then busulfan (8.8%), melphalan (5.9%), and cyclophosphamide (2.9%).

There was no statistically significant relationship between the occurrence of infections (any and particular types) and GvHD or CR ( $p > 0.05$  in each case).

The statistical relationships between viral infections and TBI, GvHD, and CR status are set out in Table IV.

## Discussion

In our report, we have assessed the occurrence, etiology, risk factors and clinical outcome of viral infections in pediatric patients with ALL after allo-HSCT. Most previous studies have concerned the reactivation of viruses in the entire population of children who underwent the procedure, regardless of the disease entity being an indication for transplantation.

In the group of patients we studied, a complication in the form of a viral infection after allo-HSCT occurred more often in boys, in patients transplanted from an unrelated

**Table II.** Characteristics of patients with viral infections

Variable	N	% of all patients
<b>Number of patients</b>	<b>34</b>	
Age at HCST, years, average $\pm$ SD		8.47 $\pm$ 4.78 Range: 0.57–17.52
Sex		
Female	13	38.2
Male	21	61.8
TBI		
No	17	50.0
Yes	17	50.0
Donor type		
MMFD	2	5.9
MMUD	2	5.9
MSD	2	5.9
MUD	28	82.4
CR		
>CR1	9	26.5
CR1	24	70.6
PR	1	2.9
Conditioning regimen		
TBI-based	17	50.0
Non-based	17	50.0
Deaths	5	14.7
Deaths from infection	3	8.8
<b>Number of viral infections</b>	<b>83</b>	
Diagnostic material		
Feces	7	8.4
Urine	15	18.1
Blood plasma	42	50.6
Nasal swab	19	22.9
Treatment		
None	25	30.1
Symptomatic	21	25.3
Anti-virals	37	44.6
Time from HSCT to viral infection, days, median	83	+28 (from +4 to +85)
GvHD before viral infection		
No	65	81.3
Yes	15	18.8

HSCT – hematopoietic stem cell transplantation; SD – standard deviation; TBI – total body irradiation; MMFD – mismatched family donor; MMUD – mismatched unrelated donor; MSD – matched sibling donor; MUD – matched unrelated donor; CR1 – first complete remission; PR – partial remission; GvHD – graft-versus-host disease

donor, and in the first remission of ALL. However, the differences between the groups were not statistically significant. The median age at viral onset was ≥8 years.

Tsoumakas et al. [7], in a multivariate analysis, defined that when the recipient was ≥8 years and the transplantation came from a related donor, the patients were more prone to EBV, ADV and BKV infection.

In the study by Yamada et al. [11], the following risk factors for viremia were determined: a CMV seronegative donor (for CMV reactivation as well as for EBV, BKV, HHV-6), age ≥5 years at the time of transplantation, the use of myeloablative conditioning, and no use of cyclophosphamide after transplantation.

**Table III.** Etiology of viral infections

Virus type	N	% of viral infections
BKV	22	26.2
CMV	20	23.8
SARS-CoV-2	10	11.9
EBV	9	10.7
ADV	7	8.3
RSV	6	7.1
Norovirus	3	3.6
Rotavirus	3	3.6
Influenza	1	1.2
HHV-6	1	1.2
Parainfluenza	1	1.2
Rhinovirus	1	1.2

BKV – BK poliomavirus; CMV – cytomegalovirus; SARS-CoV-2 – severe acute respiratory syndrome coronavirus 2; EBV – Epstein Barr virus; ADV – adenovirus; RSV – respiratory syncytial virus; HHV-6 – herpes simplex virus

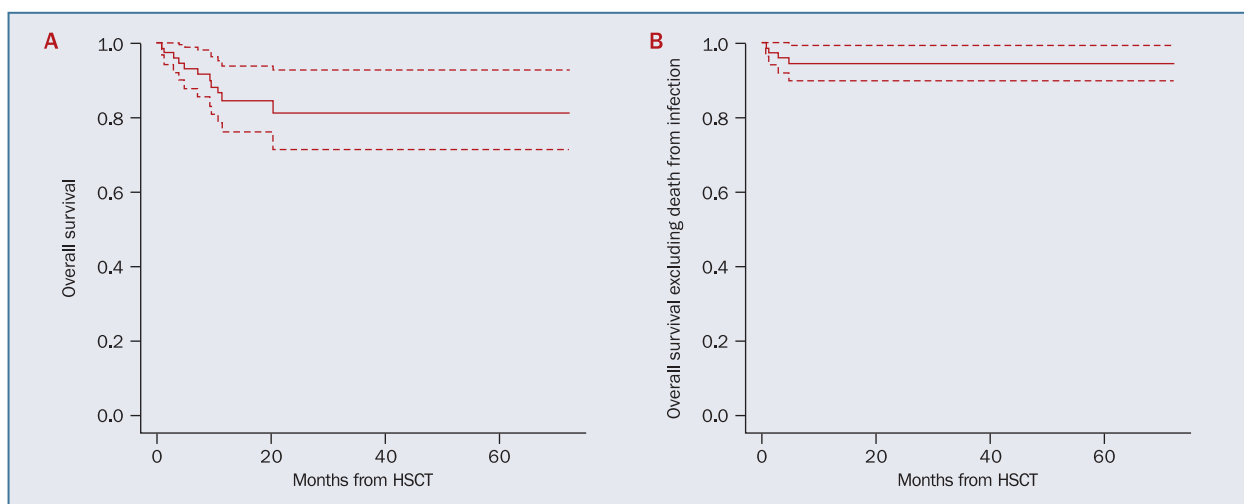
The diagnosis of aGvHD especially in stage ≥II and the onset of chronic GvHD are important risk factors for viral infections. This is due to the need for intensified immunosuppression. Moreover, the very occurrence of GvHD leads to a delay in the reconstitution of the immune system after allo-HSCT [1, 12]. In our analysis, GvHD was not related to the occurrence of viremia, although the follow-up was relatively short.

Analyzing the conditioning regimen, we encountered viremia less frequently in patients who underwent TBI. The difference between the TBI and the non-TBI group was statistically relevant. In contrast, in a retrospective analysis by Düver et al. [8], no significant association was found for TBI conditioning. Another study revealed TBI to be an independent risk factor for high CMV or EBV DNA levels [13]. Our observation could be related to the small number of patients in our study group. Moreover, a relatively large group received non-TBI conditioning (50%).

The reactivation of viral infections with viruses like BKV, CMV, and EBV is a relevant complication after HSCT, as we confirmed in our retrospective study [7, 8]. In our analysis, the reactivation of BKV was most frequently observed, followed by CMV. SARS-CoV-2 was the third most

**Table IV.** Statistical relationships between total body irradiation (TBI), graft-versus-host disease (GvHD), complete remission (CR) status, donor type, and viral infections

Variable	Yes	No	p
	N [%]		
TBI	17 (30.4)	17 (63.0)	<b>0.010</b>
GvHD	21 (36.8)	10 (45.5)	0.656
>CR1	9 (45.0)	24 (38.7)	0.813



**Figure 1A.** Overall survival of analyzed group; **B.** Overall survival of analyzed group excluding death from infection; HSCT – hematopoietic stem cell transplantation

common factor of infection, which underlines the importance of the pathogen nowadays. However, we observed neither a severe nor a fatal clinical course of coronavirus infection. Less frequently detected viruses were ADV and RSV, followed by norovirus and rotavirus.

Düver et al. [8] evaluated that HHV-6, EBV, CMV, and ADV were the most common etiological factors of viral load; a higher number of HSV infections (10.3%) and VZV (15%) were also found.

In another study, concerning both autogeneic and allogeneic transplantation, the most frequently identified virus was CMV (38%), then BKV, EBV, and ADV. Other viruses such as HHV-6, HHV-7, HSV, and VZV were of marginal importance [7].

Other studies have revealed that coronavirus occurred with a frequency of 3–6%, which was lower than we observed in our report. SARS-CoV-2 was first detected in late 2019, and so there is still a lack of multicenter analyses on its prevalence in children after allo-HSCT [14–17]. Studies on RSV after allo-HSCT put its frequency at 2–17% of transplantations, yet there are very few analyses of RSV, parainfluenza and rhinovirus in pediatric patients [18–21].

Due to the recommendation to use acyclovir prophylaxis in the guidelines, we did not analyze the viral load of HSV and VZV [22]. The selection of donors in terms of the serological status for CMV and EBV contributed to the reduction of the reactivation frequency of these viruses. Frequent monitoring of PCR viral load levels made it possible to reduce the need for causative treatment and thus lower the risk of antiviral treatment side effects. Careful selection of donors for HLA compatibility reduced the risk of GvHD, but this complication is still a significant factor in the development of infection. Mortality due to viral infections remains unacceptably high [5, 22].

Our study has several limitations. The study group contained a relatively small number of patients and the duration of follow up was limited. Factors such as recipient/donor serostatus, the type of GvHD prophylaxis, the use of T-cell depletion, the time of immunoreconstitution, and GvHD stage were not included in our analysis.

## Conclusions

In conclusion, our report describes the epidemiology and risk factors of viral infections after allo-HSCT in children with ALL. In the studied group, TBI was not conducive to viremia. Complications occurred more frequently in patients who received chemotherapy-based conditioning. GvHD, CR1 status and donor type did not impact the rate of infections. The third most commonly detected viral pathogen was SARS-CoV-2, which underscores its relevance in patients after allo-HSCT. Frequent monitoring and the assessment of risk factors, together with tailoring

immunosuppressive and antiviral therapy, are all crucial. Further studies regarding viral complications in this group of pediatric patients could reveal more specific management strategies.

## Authors' contributions

AIF and AZ-P were responsible for the conception, design of the study and acquisition of literatures for manuscript. AIF, AZ-P, KC, OG, KJ, AM, PZ-W, JF, MS-B, MU, LC-W, OZ-S shared patients' clinical data. KD, KK, JG, JS and JW were responsible for the resources. AZ-P performed the calculations. AIF, AZ-P were responsible for the interpretation of the results. AIF prepared final manuscript for publication, supervised by AZ-P. All authors discussed the results and contributed to the final manuscript.

## Conflict of interest

The authors declare no conflict of interest.

## Financial support

None.

## Ethics

The work described in this article has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans; EU Directive 2010/63/EU for animal experiments and uniform requirements for manuscripts submitted to biomedical journals.

## References

1. Zajac-Spychala O, Kampmeier S, Lehrnbecher T, et al. Infectious complications in paediatric haematopoietic cell transplantation for acute lymphoblastic leukemia: current status. *Front Pediatr.* 2022; 9: 782530, doi: [10.3389/fped.2021.782530](https://doi.org/10.3389/fped.2021.782530), indexed in Pubmed: [35223707](https://pubmed.ncbi.nlm.nih.gov/35223707/).
2. Olkinuora HA, Taskinen MH, Saarinen-Pihkala UM, et al. Multiple viral infections post-hematopoietic stem cell transplantation are linked to the appearance of chronic GVHD among pediatric recipients of allogeneic grafts. *Pediatr Transplant.* 2010; 14(2): 242–248, doi: [10.1111/j.1399-3046.2009.01226.x](https://doi.org/10.1111/j.1399-3046.2009.01226.x), indexed in Pubmed: [19691523](https://pubmed.ncbi.nlm.nih.gov/19691523/).
3. Alexandersson A, Koskenvuo M, Tiderman A, et al. Viral infections and immune reconstitution interaction after pediatric allogeneic hematopoietic stem cell transplantation. *Infect Dis (Lond).* 2019; 51(10): 772–778, doi: [10.1080/23744235.2019.1650198](https://doi.org/10.1080/23744235.2019.1650198), indexed in Pubmed: [31380705](https://pubmed.ncbi.nlm.nih.gov/31380705/).
4. Silcock R, Mitchell K, Fraser C, et al. Epidemiology and outcome for viremia in children undergoing bone marrow transplant: A retrospective cohort study. *Transpl Infect Dis.* 2021; 23(4): e13580, doi: [10.1111/tid.13580](https://doi.org/10.1111/tid.13580), indexed in Pubmed: [33533068](https://pubmed.ncbi.nlm.nih.gov/33533068/).
5. Annaloro C, Serpenti F, Saporiti G, et al. Viral infections in HSCT: detection, monitoring, clinical management, and immunologic implications. *Front Immunol.* 2020; 11: 569381, doi: [10.3389/fimmu.2020.569381](https://doi.org/10.3389/fimmu.2020.569381), indexed in Pubmed: [33552044](https://pubmed.ncbi.nlm.nih.gov/33552044/).



6. Savolainen H, Lautenschlager I, Piiparinen H, et al. Human herpesvirus-6 and -7 in pediatric stem cell transplantation. *Pediatr Blood Cancer*. 2005; 45(6): 820–825, doi: [10.1002/psc.20337](https://doi.org/10.1002/psc.20337), indexed in Pubmed: [15700258](https://pubmed.ncbi.nlm.nih.gov/15700258/).
7. Tsoumakas K, Giamaïou K, Goussetis E, et al. Epidemiology of viral infections among children undergoing hematopoietic stem cell transplant: a prospective single-center study. *Transpl Infect Dis*. 2019; 21(4): e13095, doi: [10.1111/tid.13095](https://doi.org/10.1111/tid.13095), indexed in Pubmed: [30993823](https://pubmed.ncbi.nlm.nih.gov/30993823/).
8. Düver F, Weißbrich B, Eyrich M, et al. Viral reactivations following hematopoietic stem cell transplantation in pediatric patients – a single center 11-year analysis. *PLoS One*. 2020; 15(2): e0228451, doi: [10.1371/journal.pone.0228451](https://doi.org/10.1371/journal.pone.0228451), indexed in Pubmed: [32017805](https://pubmed.ncbi.nlm.nih.gov/32017805/).
9. Czyżewski K, Styczyński J. Real-world experience with letermovir in primary prophylaxis of cytomegalovirus in adult patients after hematopoietic cell transplantation: summary of reported data. *Acta Haematol Pol*. 2021; 52(3): 182–189, doi: [10.5603/ahp.2021.0035](https://doi.org/10.5603/ahp.2021.0035).
10. Gil L. Cytomegalovirus and invasive fungal disease: trolls of hematopoietic cell transplantation. *Acta Haematol Pol*. 2021; 52(5): 453–454, doi: [10.5603/ahp.2021.0086](https://doi.org/10.5603/ahp.2021.0086).
11. Yamada M, Sakamoto K, Tomizawa D, et al. A prospective viral monitoring study after pediatric allogeneic hematopoietic stem cell transplantation for malignant and nonmalignant diseases. *Transplant Cell Ther*. 2021; 27(10): 872.e1–872.e8, doi: [10.1016/j.jtct.2021.07.014](https://doi.org/10.1016/j.jtct.2021.07.014), indexed in Pubmed: [34298243](https://pubmed.ncbi.nlm.nih.gov/34298243/).
12. Dziedzic M, Sadowska-Krawczenko I, Styczyński J. Risk factors for cytomegalovirus infection after allogeneic hematopoietic cell transplantation in malignancies: proposal for classification. *Anticancer Res*. 2017; 37(12): 6551–6556, doi: [10.21873/anticancer.12111](https://doi.org/10.21873/anticancer.12111), indexed in Pubmed: [29187429](https://pubmed.ncbi.nlm.nih.gov/29187429/).
13. Kullberg-Lindh C, Mellgren K, Friman V, et al. Opportunistic virus DNA levels after pediatric stem cell transplantation: serostatus matching, anti-thymocyte globulin, and total body irradiation are additive risk factors. *Transpl Infect Dis*. 2011; 13(2): 122–130, doi: [10.1111/j.1399-3062.2010.00564.x](https://doi.org/10.1111/j.1399-3062.2010.00564.x), indexed in Pubmed: [21457420](https://pubmed.ncbi.nlm.nih.gov/21457420/).
14. Chandar R, Swaminathan V, Meena S, et al. The impact of COVID-19 in children post hematopoietic stem cell transplantation: experience from a pediatric transplant unit in India. *Pediatric Hematol Oncol J*. 2022; 7(2): 45–48, doi: [10.1016/j.phoj.2021.12.003](https://doi.org/10.1016/j.phoj.2021.12.003).
15. Lucchini G, Furness C, Lawson S, et al. COVID-19 infection in paediatric recipients of allogeneic stem cell transplantation: the UK experience. *Br J Haematol*. 2021; 194(4): e74–e77, doi: [10.1111/bjh.17547](https://doi.org/10.1111/bjh.17547), indexed in Pubmed: [34132400](https://pubmed.ncbi.nlm.nih.gov/34132400/).
16. Sarbay H, Atay A, Malbora B. COVID-19 infection in a child with thalassemia major after hematopoietic stem cell transplant. *J Pediatr Hematol Oncol*. 2021; 43(1): 33–34, doi: [10.1097/MPH.0000000001895](https://doi.org/10.1097/MPH.0000000001895), indexed in Pubmed: [32740278](https://pubmed.ncbi.nlm.nih.gov/32740278/).
17. Vicent MG, Martínez AP, Trabazo Del Castillo M, et al. COVID-19 in pediatric hematopoietic stem cell transplantation: The experience of Spanish Group of Transplant (GETMON/GETH). *Pediatr Blood Cancer*. 2020; 67(9): e28514, doi: [10.1002/pbc.28514](https://doi.org/10.1002/pbc.28514), indexed in Pubmed: [32573924](https://pubmed.ncbi.nlm.nih.gov/32573924/).
18. Neemann K, Freifeld A. Respiratory syncytial virus in hematopoietic stem cell transplantation and solid-organ transplantation. *Curr Infect Dis Rep*. 2015; 17(7): 490, doi: [10.1007/s11908-015-0490-9](https://doi.org/10.1007/s11908-015-0490-9), indexed in Pubmed: [26068871](https://pubmed.ncbi.nlm.nih.gov/26068871/).
19. Barral S, Mamin A, Dantin C, et al. Rhinovirus infections among hematopoietic stem cell transplant recipients: a pre-transplant dilemma? *Viruses*. 2022; 14(2), doi: [10.3390/v14020267](https://doi.org/10.3390/v14020267), indexed in Pubmed: [35215861](https://pubmed.ncbi.nlm.nih.gov/35215861/).
20. El-Bietar J, Nelson A, Wallace G, et al. RSV infection without ribavirin treatment in pediatric hematopoietic stem cell transplantation. *Bone Marrow Transplant*. 2016; 51(10): 1382–1384, doi: [10.1038/bmt.2016.124](https://doi.org/10.1038/bmt.2016.124), indexed in Pubmed: [27183091](https://pubmed.ncbi.nlm.nih.gov/27183091/).
21. Srinivasan A, Wang C, Yang J, et al. Symptomatic parainfluenza virus infections in children undergoing hematopoietic stem cell transplantation. *Biol Blood Marrow Transplant*. 2011; 17(10): 1520–1527, doi: [10.1016/j.bbmt.2011.03.001](https://doi.org/10.1016/j.bbmt.2011.03.001), indexed in Pubmed: [21396476](https://pubmed.ncbi.nlm.nih.gov/21396476/).
22. Tatebe Y, Ushio S, Esumi S, et al. Low-dose acyclovir for prophylaxis of varicella-zoster virus reactivation after hematopoietic stem cell transplantation in children. *Pediatr Blood Cancer*. 2022; 69(12): e29979, doi: [10.1002/pbc.29979](https://doi.org/10.1002/pbc.29979), indexed in Pubmed: [36151963](https://pubmed.ncbi.nlm.nih.gov/36151963/).