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Infections in Children with Cancer Admitted in an Oncology Reference Hospital: A Cross-sectional Study

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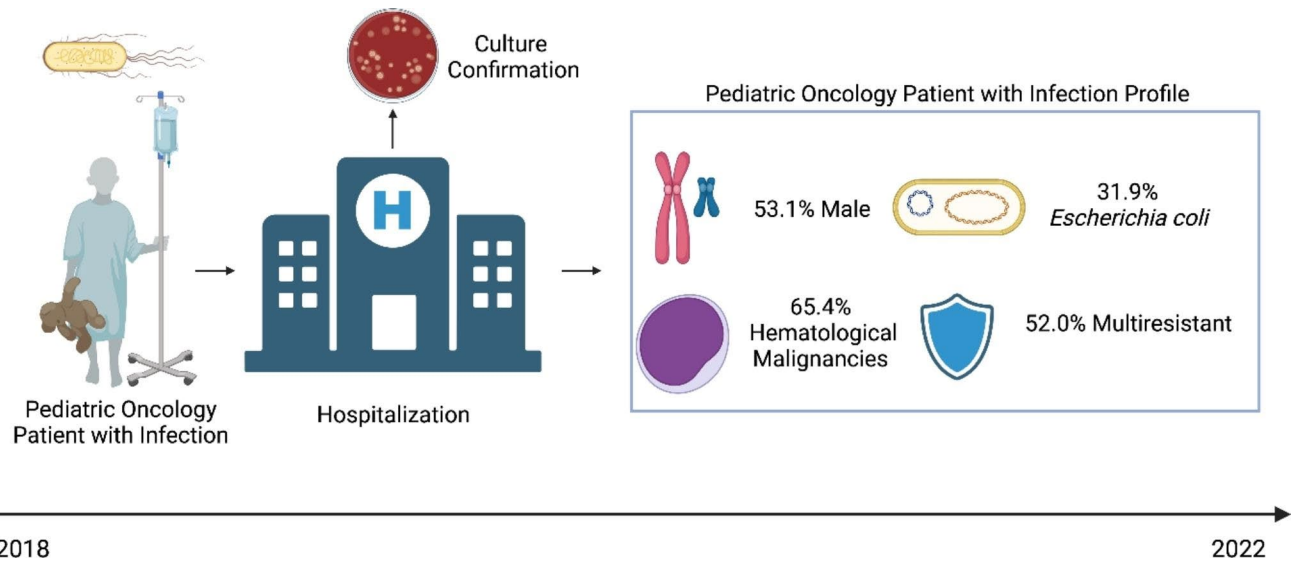
Abstract
Pediatric oncology patients are usually immunosuppressed due to factors such as the neoplasm and its treatment, making them more susceptible to infections. This article aims to determine the infection profile of pediatric oncology patients admitted to an oncology reference hospital in Natal, Rio Grande do Norte, Brazil. A retrospective and cross-sectional study was conducted, collecting data from patients hospitalized due to infection in a pediatric oncology unit exclusively for the Brazilian public health system, spanning from 2018 to 2021. A total of 168 episodes of infections were identified in 96 patients, resulting in 157 hospitalizations. Among the patients with infections, 62.4% had hematological malignancies, and out of these cases, 74.6% specifically had Acute Lymphoid Leukemia. The Escherichia coli (31.9%) was the most prevalent microorganism isolated from the samples. Multidrug-resistant microorganisms accounted for 52% of all identified microorganisms. Fluoroquinolones and beta-lactam were the most prevalent antibiotic classes in the analyzed antibiograms. Factors such as Sex, type of cancer, chemotherapy in the last 30 days, were found to be associated with the occurrence of infection ($p < 0.05$). Conducting epidemiological studies regarding infections in pediatric oncology is crucial to development of empirical protocols, and the implementation of strategies to better control future infections.



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Introduction

Pediatric oncology patients are often immunosuppressed due to their neoplasm and exposure to chemotherapy and corticosteroids, which increases their susceptibility to infections [1–3].

Infections pose a significant challenge in public health, particularly for children with cancer, as they contribute to increasing hospital admissions, prolonged hospitalization duration, and remain as the leading cause of severe treatment-related morbidity and mortality in this population [4–8],

The rise in morbidity and mortality rates among cancer patients due to infectious processes is directly linked to infections caused by multidrug-resistant microorganisms. The development of antimicrobial resistance is largely attributed to the inappropriate and unnecessary use of antimicrobials without adequate clinical indication and follow-up, underscoring the importance of establishing rational drug utilization[9–11].

Antimicrobials constitute the most commonly prescribed class of drugs for hospitalized children [12], However, it is known that a significant proportion of these prescriptions are inappropriate or unnecessary [13, 14]. In the case of oncology patients, antimicrobials are primarily employed for the treatment of opportunistic infections, as well as for empirical management of febrile neutropenia and prophylaxis [6, 15, 16].

The incidence of multidrug-resistant microorganism infections in children with cancer stands as a major driver for clinical deterioration and compromised prognosis, resulting in mortality rates exceeding 60% [1, 3, 17] Compared to pediatric non-oncology patients, pediatric oncology patients face a higher risk of infection and microbial resistance development, which may lead to unfavorable clinical outcomes [17, 18].

Hematological–oncological pediatric patients are more affected by infections caused by gram-negative, including a significant presence of *Escherichia coli*. The selection of suitable empiric antibiotic in patients with febrile neutropenia has been challenging due to the increase in multiresistent microorganisms. The development of antimicrobial resistance contributes to an increased rate of hospitalizations among pediatric oncology patients in intensive care units[19–23].

Despite the concerning number of infections in pediatric oncology patients, there is a scarcity of studies investigating the epidemiological profiles within this population. This lack of data may impede the development of empirical protocols for infection management in hospitals. Therefore, the objective of this study is to determine the epidemiological profile of infections in patients admitted to the pediatric oncology unit of the largest oncology institute in the state of Rio Grande do Norte, Brazil. Additionally, this research aims to identify the risk factors associated with the development of infections.

Materials and Methods

This retrospective and cross-sectional study was conducted in a pediatric oncology unit that exclusively serves patients receiving treatment through the Brazilian public health system, Sistema Único de Saúde (SUS), at a renowned oncology reference hospital in the city of Natal, Rio Grande do Norte, Brazil.

Location Characterization

The hospital consists of a total of 112 beds, with 8 beds dedicated exclusively to SUS pediatric patients. When the demand for hospitalization exceeds the number of beds, these pediatric patients may be admitted to other hospital wards. For this study, only hospitalizations in the exclusive SUS pediatric beds were included.

Characterization of Patients

Patients included in the study had a diagnosis of cancer, and hospitalization could be for chemotherapy administration or clinical complications. The age range for inclusion followed the guidelines of the Brazilian Society of Pediatrics for the care of children and adolescents, encompassing individuals from birth to less than twenty-one years of age[24].

Collected Data and Variables

All patients admitted to the exclusive SUS pediatric beds who had a positive microbiological test results between January 2018 and December 2021 were included in the study. Secondary patient data were collected from laboratory tests, electronic medical records, and the internal drug dispensing system of the hospital pharmacy. The collected variables included gender, age, primary neoplasm, sample collected for microbiological culture, type of microbiological culture, isolated microorganism, antimicrobials associated with the resistance profile described in the antibiogram, multidrug resistance profile, presence of extended-spectrum β-lactamase (ESBL)-producing bacteria, chemotherapy use within 30 days prior to hospitalization with infection, specific antineoplastic agents used, and the presence of febrile neutropenia upon admission.

The ESBL phenotype analysis was performed on isolates of Escherichia coli, Klebsiella pneumoniae, Klebsiella

Table 1 Characterization of patients hospitalized in Pediatrics Unity - SUS, with a positive microbiological test result, according to demographic and clinical variables from 2018 to 2021

Characteristics	Patients	Neoplasm Classification		
	(n = 96[1])	HM (n = 59[1])	ST (n = 37[1])	*p*-value[2]
		61,45%	38,5%	
Sex				0.017
Male	51 (53.1%)	37 (62.7%)	14 (37.8%)	
Age	10 (-8.75; 29.25)	9.0 (-9.62; 29.4)	11.0 (-4.0; 28.0)	0.14
Primary Neoplasm				0.032
ALL	44 (45.8%)	44 (74.6%)	-	
AML	7 (7.3%)	7 (11.9%)	-	
Hodgkins Lymphoma	3 (3.1%)	3 (5.1%)	-	
Non-Hodgkins Lymphoma	3 (3.1%)	3 (5.1%)	-	
Osteosarcoma	15 (15.6%)	-	15 (40.5%)	
Ewings sarcoma	5 (5.2%)	-	5 (13.5%)	
Medulloblastoma	4 (4.2%)	-	4 (10.8%)	
Neuroblastoma	4 (4.2%)	-	4 (10.8%)	
Others[3]	11 (11.4%)	2 (3.4%)	7 (24.3%)	

[1]n (%); median (IQR);[2] Chi-square; Fisher's exact; Wilcoxon Test; Proportion test; [3] Burkitt's Lymphoma, Hepatoblastoma, Rhabdomyosarcoma, Desmoplastic Tumor, Hepatic Angiosarcoma, Germ Cell Tumor, Primitive Neuroectodermal Tumor; HM – Hematological malignancy; ST – Solid tumor; ALL – Acute lymphoid leukemia; AML – Acute Myeloid Leukemia

oxytoca, and Proteus mirabilis, following the recommendations of the *Clinical and Laboratory Standards Institute* (CLSI) (CLSI) [25].

Primary neoplasms were classified into two subgroups: hematologic malignancies and solid tumors. Hematologic malignancies encompassed hematopoietic and lymphoid neoplasms such as leukemias and lymphomas[26]. Solid tumors were characterized by abnormal masses located in tissues, including osteosarcoma, neuroblastoma, and Ewing's sarcoma [27].

Infection information was collected based on the analysis of microbiological tests (bacterial and fungal cultures) performed by an outsourced private laboratory. The minimum inhibitory concentration results were obtained using automated methodology with the VITEK-2 system. The selection of tested antimicrobial agents followed the recommendations of the Brazilian Committee on Antimicrobial Susceptibility Testing – BrCAST 19.

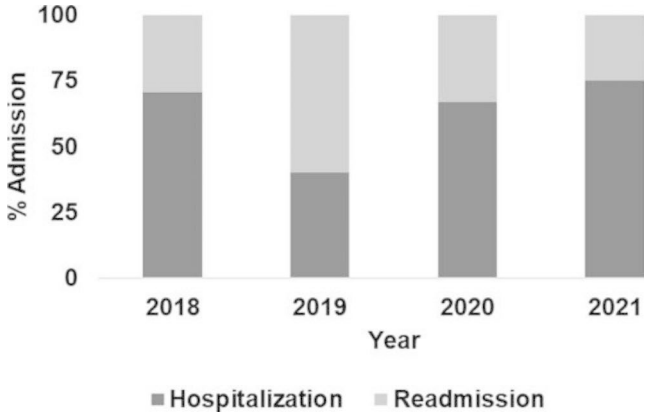

Fig. 1 Percentage of hospitalization and readmission of patients with infection and positive microbiological test from 2018 to 2021

Microorganisms were classified as multidrug-resistant based on the concept defined by Magiorakos et al. (2012) which identifies microorganisms resistant to at least three classes of antimicrobials. Resistance to a single antimicrobial from a class is sufficient to consider the microorganism resistant to the entire class [28]. Thus, ESBL-producing microorganisms were also considered multidrug-resistant, as they exhibit resistance to most antimicrobials with a beta-lactam ring, such as penicillins, first to third-generation cephalosporins, and aztreonam.

Statistical Analysis

The collected data were organized in an Excel spreadsheet and subsequently analyzed using Fisher's exact test, chi-square test, and odds ratio tests to evaluate correlations and statistical significance. A significance level of 5% (95% confidence interval) was considered. Data processing was performed using R 4.0.2 software.

Results

Characterization of Patients

There were 1,917 hospitalizations for general causes in the pediatric oncology beds exclusively dedicated to SUS between 2018 and 2021. There were 168 episodes of infection in 96 patients during 151 hospitalizations. Overall, the majority of patients were male (53.3%), and the median age of the studied patients was 10 years old (Table 1). Reinfections were reported in 29.6%, 60%, 33.3%, and 25% of patients in the years 2018, 2019, 2020, and 2021, respectively (Fig. 1).

Out of the 96 children with infection episodes, 61.45% (N = 59) had a hematologic malignancy, while 38.5% (N = 37) had a solid tumor. Acute lymphoblastic leukemia

and osteosarcoma were the most frequently identified types of neoplasms in patients who experienced infections during hospitalization, accounting for 45.8% and 15.6%, respectively (Table 1). Statistically significant associations were observed between infections and the sex and primary neoplasm of the patients.

We identified that in 121 hospitalizations and 134 infection cases, patients had received chemotherapy (80.1%; $P < 0.001$) within 30 days before the diagnosis of infection. The most commonly used antineoplastic agents were methotrexate (53%), cytarabine (35.8%), vincristine (32.1%), and doxorubicin (31.3%). There was no statistical significance in the frequency of febrile neutropenia cases (43.7%; $P = 0.28$) during hospitalization with infection episodes.

Infection Profile

Gram-negative bacterial infections (71.05%) were prevalent among hospitalized patients during the study period. *Escherichia coli* was the most frequently identified infective organism, responsible for 52 (31.9%) infection cases, followed by *Klebsiella pneumoniae* (13.5%) and *Staphylococcus epidermidis* (7.4%). There was no statistically significant association between the infection profile and the primary neoplasm ($P > 0.05$) (Table 2).

We observed an increase in *Escherichia coli* infections over the years, with its involvement in 19% of all infections in 2018 and 37.1% in 2021. Additionally, from 2018 to 2020, no *Acinetobacter baumannii* infections had been

Table 2 Characterization of confirmed infections in pediatric oncology patients admitted to Pediatrics Unity - SUS by type of neoplasm from 2018 to 2021

Characteristics	Infections (n = 168[1])	Neoplasm classification		*p*-valor[2]
		HM (n = 108[1])	ST (n = 60[1])	
Gram classification				0.91
Gram-negative	108 (71.1%)	66 (70.2%)	42 (72.4%)	
Gram-positive	44 (28.9%)	28 (29.8%)	16 (27.6%)	
Bacteria				0.68
Escherichia coli	52 (31.9%)	34 (32.7%)	18 (30.5%)	
Klebsiella pneumoniae	22 (13.5%)	14 (13.5%)	8 (13.6%)	
Staphylococcus epidermidis	12 (7.4%)	6 (5.8%)	6 (10.2%)	
Pseudomonas aeruginosa	11 (6.7%)	8 (7.7%)	3 (5.1%)	
Staphylococcus haemolyticus	8 (4.9%)	6 (5.8%)	2 (3.4%)	
Others[3]	47 (28.6%)	26 (26.1%)	21 (35.7%)	
Multiresistance				0.83
Yes	79 (52.0%)	50 (53.2%)	29 (50.0%)	
No	73 (48.0%)	44 (46.8%)	29 (50.0%)	
Fungi				0.17
Candida parapsilosis	5 (3.0%)	5 (4.6%)	-	
Candida albicans	4 (2.4%)	4 (3.7%)	-	
Candida Sp.	2 (1.2%)	1 (0.9%)	1 (1.7%)	
Others[4]	5 (3.0%)	4 (3.6%)	1 (1.7%)	
Resistance				0.33
Not resistant	6 (37.5%)	6 (42.9%)	-	
Resistant	3 (18.7%)	2 (14.2%)	1 (50.0%)	
Not performed[5]	7 (43.8%)	6 (42.9%)	1 (50.0%)	
Material Collected				0.27
PA blood	48 (28.6%)	36 (33.3%)	12 (20.0%)	
TIC and PA blood	36 (21.4%)	20 (18.5%)	16 (26.7%)	
TIC blood	26 (15.5%)	16 (14.8%)	10 (16.7%)	
Urine	41 (24.4%)	26 (24.1%)	15 (25.0%)	
Other[6]	17 (10,1%)	10 (9.3%)	7 (11.6%)	

[1]n (%);[2] Chi-square; Fisher's exact; Proportion test; [3] Bacteria with less than eight cases: Enterobacter cloacae, Staphylococcus hominis, Enterococcus faecalis, Klebsiella oxytoca, Acinetobacter baumannii, Staphylococcus warneri, Stenotrophomonas maltophilia, Morganella morganii, Streptococcus pneumoniae, Burkholderia cepacia, Enterobacter aerogenes, Kocuria rhizophila, Proteus penneri, Rothia dentocariosa, Salmonella group, Serratia marcescens, Sphingomonas paucimobilis, Staphylococcus aureus, Staphylococcus capitis, Staphylococcus kloosii, Staphylococcus lugdunensis, Staphylococcus pseudintermedius, Staphylococcus saprophyticus, Streptococcus mitis, Turicella otitidis; [4] Fungi with less than two cases: Aspergilus sp., Candida famata, Candida haemulonii, Candida krusei, Trichosporon; [5] Fungi for which a resistance profile was not performed in culture; PA – Peripheral Access; TIC - Totally Implantable Catheter, [6] sputum, abdominal fluid, bone fragment, tracheal aspirate, Catheter tip, Ear Secretion, Wound Secretion

identified, but in 2021, three cases (8.6%) were reported (Supplementary Table S1).

Out of a total of 79 infection episodes (52%; P = 0.83), multidrug-resistant bacteria were the cause, with a reduction over the years. In 2018, the percentage was 50%, while in 2021, it decreased to 40% (Supplementary Table S1). The proportion of infections due to multidrug-resistant bacteria was similar in children with solid tumors and hematological malignancies.

Regarding fungal infections, *Candida parapsilosis* had a higher occurrence, accounting for 3% of all infections. Most of these infections were observed in patients with hematological malignancies (12.8%; P = 0.17). Antifungal susceptibility testing (antifungigram) was performed on nine infections, and Amphotericin-B, Flucytosine, and Voriconazole were the antifungals tested. Most of the identified fungi showed susceptibility to multiple antifungal agents, as seen in Table 2.

Peripheral access and totally implanted catheters were the most frequently used materials (65.5%; P = 0.27) for collecting samples for microbiological culture. No statistically significant association was found between the collected materials and the occurrence of infection (Table 2).

The ESBL phenotype test was performed on 78 isolated bacteria. Out of these, 43 samples (55.1%) tested positive. Considering that there were 168 infections in the study period, the 43 infections caused by ESBL-positive bacteria accounted for 25.5% of all infections. *E. coli* was the main ESBL-producing bacteria, responsible for 69.8% of all ESBL-positive infections. Furthermore, an increase in the prevalence of this microorganism was observed over the years (Table 3).

The available antibiogram data were reviewed to elucidate antibiotic susceptibility patterns. It was found that out of the 168 identified infections, 129 were caused by bacteria resistant to at least one antibiotic, thus considered multidrug-resistant. The predominant resistance was observed against ciprofloxacin (49.6%), ampicillin (43.4%), ceftriaxone (40.3%), and cefepime (35.5%) (Supplementary Table S2).

Table 3 ESBL-positive isolates from 2018 to 2021 in patients hospitalized in Pediatrics Unity - SUS

Bacteria	Overall Sample (n = 78[1])	2018 (n = 18)	2019 (n = 22)	2020 (n = 20)	2021 (n = 118)
E. coli	30 (69.8%)	1 (25.0%)	8 (66.7%)	15 (83.3%)	6 (66.7%)
K. pneumoniae	9 (20.9%)	3 (75.0%)	3 (25.0%)	-	3 (33.3%)
K.oxytoca	4 (9.3%)	-	1 (8.3%)	3 (16.7%)	-

[1]n (%)

Discussion

In this study, a survey of epidemiological and clinical data related to pediatric oncology patients, hospitalized in a unit with exclusive beds for the SUS, who presented infection during their hospitalization. Infectious diseases are associated with a high rate of mortality and morbidity among children with cancer that are treated with chemotherapy [29].

There were no significant differences in the number of infections over the four years evaluated. This suggests a multimorbidity in these patients compared to non-oncological children, as they tend to have a higher frequency of hospitalization for various reasons, including infections [30].

In 2020 started to the Covid-19 pandemic began in Brazil, caused by the SARS-CoV-2 coronavirus, lasting into 2021. During this period the number of admissions due to non-covid has reduced considerably[31, 32].

A multicenter, international, collaborative cohort study evaluated the impact of the Covid-19 pandemic on pediatric cancer patients in low-income, middle-income, and high-income countries. The results revealed that the majority of pediatric cancer patients have continued to receive the standard of care they would have received prior to the pandemic. However, the patients most affected by the pandemic were those with pediatric cancer in low-income and middle-income countries [33]. Our findings support the observations presented in that study, as we observed no significant change in the number of hospitalizations in the investigated pediatric unit. This stability may be attributed to the specialized care required by cancer patients, the awareness of the children's families regarding the importance of hospital care, and the institution's commitment to providing care for patients even amidst the challenges posed by the pandemic.

The World Health Organization has reported that hematological malignancies are the most common neoplasms in children, with acute lymphoid leukemia being the most prevalent [34, 35]. Our results also indicate that acute lymphoid leukemia was the predominant neoplasm among pediatric oncology patients with infectious processes. However, it is important to highlight that among patients with solid tumors, osteosarcoma was the most common neoplasm. A study conducted by Garrido et al. (2019) evaluated the epidemiological, clinical, and microbiological features of bloodstream infections in children with cancer, and their results showed a higher number of patients with solid tumors experiencing infections (72.85%). In that study, 40.3% of patients with hematologic malignancies and infections were diagnosed with acute lymphoid leukemia. There was a predominance of male patients in both neoplasm classifications [36].

In this study, we found that the number of infection cases (N = 168) was higher than the number of hospitalizations

(N = 151), which in turn was higher than the number of hospitalized patients (N = 96). This indicates that the same patient could be hospitalized more than once in a year and develop more than one infection during the same hospitalization. Recurrent infections can be attributed to the immunosuppression inherent in pediatric oncology patients, whether due to the primary neoplasm or the chemotherapy used. The occurrence of febrile neutropenia, a condition characterized by a drop in neutrophil count below 500/mm³ or less than 1000/mm³, is not uncommon. The main clinical warning sign is post-chemotherapy fever. However, some patients may present other symptoms such as hypothermia, hypotension, and mental confusion instead of fever [37]. Neutropenia is associated with the risk of infections, leading to hospitalizations in intensive care units and, in some cases, death [8, 37, 38].

Although the number of hospitalizations has remained constant over the years, the percentage of readmissions has significantly dropped from 60% to 2019 to 25% in 2021. There has also been a reduction in the number of patients with febrile neutropenia.

Additionally, we found a significant relationship between children with infections during hospitalization and undergoing chemotherapy within the previous 30 days ($P < 0.001$). It is suggested that undergoing chemotherapy may be a risk factor for the occurrence of infections. When considering post-chemotherapy infections in pediatric oncology patients, attention should also be given to other factors associated with the occurrence of infections in this population, such as qualitative hematological changes, the use of central venous catheters, and disruption of the skin-mucosal barrier [37].

The main chemotherapy protocols used in pediatric hematological cancer treatment commonly involve antineoplastic agents such as vincristine, cytarabine, anthracyclines, and methotrexate[39]. These drugs promote hematological toxicity, leading to neutropenia and making the patient more susceptible to infections. Methotrexate and cytarabine are also associated with the occurrence of oral mucositis, a clinical condition mainly related to fungal infections [40]. Osteosarcoma is a predominantly pediatric neoplasm [41], and its chemotherapy treatment has a high immunosuppressive potential due to the high doses of methotrexate, ifosfamide, and cisplatin [42], which further increases the patient's susceptibility to infections.

Our findings revealed that infections caused by Gram-negative bacteria were predominant in pediatric oncology, with *Escherichia coli* being the most frequently isolated organism (Table 2). The epidemiological profile of infections in recent years, both in the oncological and general context, shows a prevalence of Gram-negative bacterial infections in various types of infectious foci [16, 21, 43]–[45]. These findings also indicate the predominance of infections caused by *E. coli and K. pneumoniae* in this population [11, 46].

E. coli is an important nosocomial pathogen with antimicrobial resistance profile [19, 23]. Frequently, neutropenic cancer patients are infected with *E. coli* that are endogenously acquired through gastrointestinal tract after initiation of cytotoxic chemotherapy. A study carried out with children with cancer, with the objective of determining the prevalence of infections by gram-negative bacteria using a phenotypic screening test, in addition to molecular assays, demonstrated a prevalence of infections by *E. coli* [47]. The presence of the ESBL gene, which confers resistance to *E. coli* to classes of antimicrobials, may be a factor in the incidence of infection. Invasive procedures, specifically catheterization, prolonged hospitalization and confinement in an oncology unit have been associated with ESBL production [48].

We observed that 52% of the infection cases were caused by multidrug-resistant bacteria, which is a concerning fact that emphasizes the need to review empiric antibiotic regimens and prophylaxis. The resistance profile of bacteria to antimicrobials is influenced by the patterns of antibiotic usage in each population and region [49]. The limitation of antibiotic options due to bacterial resistance is particularly significant in pediatric infections, as there are fewer options available compared to adults [50].

Bacteria producing ESBL (extended-spectrum beta-lactamases) isolated in hospitals are considered one of the main causes of multidrug resistance. The most commonly isolated bacterium among ESBL-positive strains was Escherichia coli, accounting for 30 infections (69.8%), with a significant increase over the years. The development of bacterial resistance to first- and third-generation cephalosporins, mediated by ESBL production, has been increasing in recent years [51]. ESBL resistance genes are usually located on plasmids, which allows them to be transferred between bacteria of the Enterobacteriaceae family, facilitating their dissemination. These plasmids may also carry additional genes for resistance to fluoroquinolones, trimethoprim-sulfamethoxazole, and aminoglycosides, making the treatment of infections more challenging [50].

In the institution where this study was performed, ciprofloxacin is used for treatment of urinary tract infections [52, 53], the second most prevalent infectious focus in the population of this study (Table 2). Ciprofloxacin is also used in the prophylaxis against infections in patients with high-risk acute lymphoid leukemia.

Antibiotic prophylaxis with ciprofloxacin may be related to the reduction in the number of cases of infection in patients with acute lymphoid leukemia along the years (Supplementary Table S1). However, it can be considered that coverage for Gram-negatives is not being effective,

considering the high number of infections by these bacteria and their high level of resistance to ciprofloxacin.

Cefepime is empirically used for patients with febrile neutropenia, following the institutional protocol and recommendations in the literature [54, 55]. We observed a reduction in the sensitivity profile of bacteria to cefepime. In 2018, 18.9% of the bacteria were resistant to this fourth-generation cephalosporin, and by 2021, it had increased to 38.5% (Supplementary Table S2). Adhering to the institutional protocol, ensuring proper suspensions at the correct time, and using the correct dosage for each indication are essential for patient safety regarding the development of infections caused by multidrug-resistant bacteria, and it is the responsibility of the health professionals in the pediatric unit to ensure compliance.

The use of invasive accesses is also a risk factor for the development of infections in pediatric oncology patients [1–3]. We identified a higher prevalence of bloodstream infections, with 15.5% of the infections related to totally implantable catheters when analyzed separately, 21.4% when considering paired samples, and 3% for the catheter tip (Table 2). Totally implantable catheters are widely used in patients with cancer as they are ideal for administering vesicant drugs, offering a low risk of chemotherapy extravasation [56, 57]. However, this type of device is also associated with a risk of infections due to high levels of skin colonization at the insertion site and catheter connectors, as well as the administration of blood products and parenteral nutrition. Preventive measures, such as proper hygiene of the catheter site, minimizing hospitalization time, selecting the appropriate catheter type, and implanting it at the right time, can help reduce the occurrence of infections in children with cancer [58].

This study has some limitations, including the retrospective data collection and potential underreporting of some data in medical records.

Conclusion

In conclusion, our results demonstrate high incidence of Gram-negative bacteria infection, mainly multidrug-resistant bacteria. Sex, primary neoplasm and chemotherapy treatment within 30 days were factors associates with the development of infections in children with cancer. This study contributes to the improvement of empirical antibiotic therapy protocols, antibiotic prophylaxis and raising discussions about preventive measures for new infections in this population. Investigating other risk factors for the development of infections in pediatric patients with cancer should be a significant public health priority. Additionally, effective strategies for infection prevention, such as policies controlling antibiotic usage, need to be enforced and implemented to prevent the emergence of new generations of drug-resistant microorganisms. Epidemiological studies for the oncological pediatric population are scarce in the literature. Interventions with the medical and multidisciplinary team including creating awareness and establishment of robust infection control and antibiotic stewardship program are the most important strategies to implement.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00284-023-03420-y.

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Author Contributions JFVF: responsible for conceptualization, methodology, formal analysis, investigation, writing - manuscript drafting. VNR: contributed to data collection - manuscript drafting. AMAdoN: conducted the methodology, formal analysis, and writing - review and editing. MMAdeM: responsible for conceptualization, methodology, writing - review and editing, supervision and project administration. All authors contributed equally toward the elaboration of the manuscript and have given their approval of the final version.

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Declarations

Ethical Approval The project was submitted to the Ethics and Research Committee and approved with CAAE 52958021.6.0000.5293. As secondary data were obtained, this work did not require the application of a free and informed consent.

Conflicts of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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