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Clinical characteristics and short-term outcomes of pediatric lymphoma: a retrospective cohort study from a large tertiary hospital in a low- and middle-income country

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The incidence of childhood cancer has increased, with lymphoma being the third most common malignancy in children and showing improved survival rates. This study aimed to analyse the demographic, clinical, and outcome data of pediatric lymphoma patients, compare the characteristics of the HL and NHL subtypes, and evaluate treatment outcomes. A single-center retrospective cohort study was conducted at An-Najah National University Hospital (NNUH) in Palestine from 2013 to 2023. Seventy-five pediatric patients (≤18 years) newly diagnosed with Hodgkin lymphoma (HL) or non-Hodgkin lymphoma (NHL) were included, and data from electronic medical records were used. Follow-up data were analysed via Kaplan–Meier survival curves to determine event-free survival (EFS) and overall survival (OAS).This study revealed a male predominance in both NHL (1.9:1) and HL (1.3:1) patients, with a mean age of 9 years for NHL patients and 10 years for HL patients. The majority of patients were from the West Bank (56%) or Gaza (44%). NHL patients commonly presented with GI symptoms (31.7%), whereas HL patients (70.6%) presented with neck masses. B symptoms were more common in HL patients (55.9%). The tumor stage also differed, with NHL often being stage III and HL being stage II. The predominant subtypes were Burkitt's lymphoma (BL) for NHL and classical nodular sclerosis for HL. Overall survival was 96%, with 4% mortality. During the follow-up period (mean 26.5 ± 18 months), 84% of the patients had events, with 86.7% of patients remaining event-free. Relapse occurred in 13.3% of patients, predominantly in the NHL group, and the prevalence of OAS was 96%. The 2-year event-free survival (EFS) rate was 85.1%, and the 2-year overall survival (OAS) rate was 96.6%, as estimated via Kaplan–Meier survival analysis. Our study provides insights into the clinical characteristics and short-term outcomes of pediatric lymphoma patients in Palestine. Pediatric lymphoma is more common in males and primarily affects children over 10 years of age. HL is less prevalent, has a higher survival rate, and most commonly presents with a neck mass. In contrast, NHL is more common, is associated with higher relapse and mortality rates, and often presents with gastrointestinal symptoms. Burkitt's lymphoma (BL) is the most common NHL subtype and is not strongly associated with B symptoms. These findings emphasize the importance of early diagnosis and continuous follow-up in optimizing treatment outcomes. Further studies with larger cohorts and longer follow-up periods are needed to validate these findings and assess long-term survival and cure rates.

Keywords Lymphoma, Pediatric patients, Treatment outcome, Retrospective studies

Abbreviations

ALCL	Anaplastic large-cell lymphoma
BL	Burkitt's lymphoma
BM	Bone marrow
CNS	Central nervous system
CT	Computed tomography

CSF	Cerebrospinal fluid
DLBCL	diffuse large B-cell lymphoma
EBV	Epstein–Barr virus
EFS	Event-free survival
GI	Gastrointestinal
HIV	human immunodeficiency virus
HL	Hodgkin lymphoma
LDH	Lactate Dehydrogenase
LL	Lymphoblastic lymphoma
MRI	Magnetic Resonance Imaging
NHL	Non-Hodgkin lymphoma
NNUH	An-Najah National University Hospital
OAS	Overall survival
PET	Positron emission tomography

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Lymphoma, a malignancy affecting the lymphatic system, ranks as the third most prevalent cancer among children. Hodgkin lymphoma (HL) and non-Hodgkin lymphoma (NHL) account for approximately 6–8% each of the pediatric cancers[1,2]. HL, known for its high cure rates, presents pathologically as classical and nodular HL, with nodular sclerosis comprising the majority of childhood cases[3–5]. Childhood NHL includes Burkitt's lymphoma (BL), lymphoblastic lymphoma (LL), diffuse large B-cell lymphoma (DLBCL), and anaplastic large-cell lymphoma (ALCL)[6].

HL comprises 6% of childhood cancers in wealthy countries[7]whereas NHL accounts for 7% and primarily occurs in the second decade of life[7]. NHL has an age-adjusted incidence rate of 1.1 per 100,000, which is greater than the HL rate of 0.6 per 100,000 among children under the age of 15[8].

Accurate diagnosis requires biopsy and staging, and treatment is tailored to biological characteristics[9,10]. Survival outcomes have significantly improved in high-income countries, with the 5-year relative survival rate of HL increasing to 99% and that of NHL increasing to 85–95%[8], with relapse being the principal cause of treatment failure[11]. In contrast, children in Palestine face considerable challenges in terms of diagnosis and treatment because of the fragmented healthcare systems between the West Bank and Gaza, frequent restrictions on patient movement, and variable access to oncological medications. These barriers can result in delayed diagnosis, interrupted chemotherapy protocols, and suboptimal follow-up, which are factors that may negatively impact outcomes. Despite these challenges, very few studies have examined pediatric lymphoma within this unique sociopolitical and healthcare context.

Although regional studies on pediatric hematologic cancers exist, most focus on leukemia rather than lymphoma. For example, studies from An-Najah National University Hospital (NNUH) in Palestine and Gaza City have reported mainly on pediatric leukemia, with limited data on lymphoma treatment and outcomes[12,13]. In neighboring regions, a higher incidence of BL has been noted in Gaza and the West Bank, but specific treatment outcomes for pediatric lymphoma are scarce[14]. Research from Israel on pediatric NHL has shown better survival rates due to access to advanced care, although these findings may not be fully applicable to Palestine[15].

Although HL and NHL differ in biology and treatment, we present their characteristics side-by-side only for descriptive clarity while preserving analytical separation.

This study aims to address this gap by focusing specifically on pediatric lymphoma in Palestine and analysing the clinical features and short-term outcomes of pediatric lymphoma patients treated at NNUH during our follow-up period. NNUH is located in Nablus, in the northern West Bank, and serves as a referral center for pediatric oncology cases from both the West Bank and Gaza.

Given the geopolitical fragmentation and unequal distribution of cancer services between Gaza and the West Bank, there is a pressing need for data from institutions such as NNUH, which serve as central referral hubs. Understanding pediatric lymphoma in this context is essential for informing national treatment strategies, especially in the absence of centralized registries and standardized protocols across the territory.

By providing much-needed data, this study contributes to the understanding and treatment of pediatric lymphoma in resource-limited settings.

Our objectives were to study the clinical profile of pediatric lymphoma patients from 2013 to 2023 in terms of demographic data; to describe the clinical history of patients at presentation and admission; to review labs for initial admission, including complete blood count; lactate dehydrogenase (LDH) level; bone marrow (BM) biopsy; immunohistochemistry; and whole-body computed tomography (CT) and positron emission tomography (PET) scans and to study short term outcomes.

Methods

Study design and setting

A single-center, retrospective cohort study was conducted in 2023 at NNUH, a leading referral cancer center in the West Bank and Gaza, Palestine, to investigate the clinical profile and treatment outcomes of pediatric lymphoma patients treated from January 1, 2013, to December 31, 2022.

Study population and sampling

Patients were identified through electronic medical records at the Pediatric Oncology Department. All pediatric patients (≤ 18 years) with a confirmed diagnosis of HL or NHL who initiated treatment at NNUH between January 2013 and December 2022 were eligible for inclusion. Patients were excluded if they were diagnosed at NNUH but chose to begin treatment at another institution ($n = 9$), had relapsed disease at the time of initial presentation ($n = 5$), or had incomplete medical records ($n = 7$). A total of 75 patients met the inclusion criteria and were included in the final analysis.

Data collection

The collected data included demographic factors (age, sex, residence), clinical presentation (e.g., neck mass, B symptoms), lymphoma type and subtype (HL or NHL), tumor site (e.g., head/neck, mediastinal), staging (Ann Arbor for HL, St. Jude for NHL)[16,17]B symptoms, LDH levels (< 320 or ≥ 320 U/L)[18], and CNS and BM involvement. First-line treatment protocols followed international pediatric oncology guidelines. For HL, patients were treated with ABVD (adriamycin, bleomycin, vinblastine, and dacarbazine) or OEPA/COPDAC-based regimens. NHL patients receive risk-adapted multiagent chemotherapy, such as BFM protocols, on the basis of the BL and LL classifications. Salvage therapy in relapsed patients included intensive reinduction with ICE (ifos, carboplatin, etoposide) or other high-risk regimens when clinically indicated.

The selection of treatment regimens was guided by international pediatric oncology standards; however, their implementation was influenced by local drug availability. Some regimens, including salvage protocols such as ICE, are used on the basis of availability through the hospital formulary or support from humanitarian donations. Delays or substitutions occasionally occurred due to supply interruptions.

The outcome measures included death, relapse, remission, overall survival (OAS), and event-free survival (EFS) rates. *Relapse* was defined as the recurrence of lymphoma after remission, which was identified by positron emission tomography (PET) or other diagnostic imaging, such as computed tomography (CT), magnetic resonance imaging (MRI), or chest X-ray. *Remission* was defined as the absence of detectable disease activity on diagnostic imaging following treatment at the last recorded follow-up. Cures that require sustained remission over a prolonged period, typically five years or more, as suggested by the National Cancer Institute, or up to 10 years, as suggested by Cancer Research UK[19,20]could not be evaluated because of the study's limited follow-up duration (mean 26.5 ± 18 months). Given this timeframe, remission and EFS were used as primary outcomes, as they better reflect the short- to medium-term prognosis in pediatric lymphoma patients. Each patient's OAS status was determined on the basis of their survival at the last hospital follow-up. EFS and OAS were estimated via Kaplan–Meier survival analysis. EFS was defined as the time from diagnosis to the first documented relapse or death from any cause, with patients who had not experienced an event at their last follow-up being censored. OAS was defined as the time from diagnosis to death from any cause, with patients who were alive at their last follow-up being censored. Survival probabilities were calculated at 2 years (24 months) on the basis of Kaplan–Meier estimates rather than direct event counts. Patients who were transferred to another institution were censored at their last known follow-up to ensure accurate survival estimates without overestimation of mortality.

Statistical methods

The data were analysed via IBM SPSS v.29.0. Continuous variables are presented as the means ± standard deviations (SDs) or medians with interquartile ranges, whereas categorical variables are reported as frequencies and percentages. The chi-square test or Fisher's exact test was used to analyse categorical variables. Descriptive and inferential analyses were conducted, with statistical significance set at $P < 0.05$. Patients who were transferred to another hospital after completing their full treatment at our center were included in the analysis, as they met the inclusion criteria and were followed until transfer. Since their outcomes were known up to their last follow-up, they were handled as follows: In the EFS analysis, these patients were recorded as events if they experienced relapse before transfer. In the OS analysis, these patients were censored at the time of transfer in the Kaplan–Meier survival analysis, as they were still alive at the last follow-up, but their posttransfer survival was unknown. This approach ensures that survival time **is** accounted for without overestimating mortality. Supplementary analyses included unstratified survival comparisons across the full cohort (HL and NHL combined) to explore broader patterns. However, given the distinct biology and treatment of HL and NHL, all the main inferential analyses in the manuscript were performed separately by subtype.

Ethical considerations

The study protocol was approved by the Institutional Review Board (IRB) at An-Najah National University and the clinical research center at NNUH. This approval granted access to patient clinical data, which were used exclusively for the purpose of this research. All the data were kept confidential and were not used for any other purpose. All methods were performed in accordance with the relevant guidelines and regulations, including those outlined by the Declaration of Helsinki and the journal's ethical policies for research involving human participants.

Results

Demographic data

After applying the exclusion and inclusion criteria, a collective of 75 pediatric lymphoma patients (56% from the West Bank & 44% from Gaza) were identified from the medical records of the pediatric oncology department of NNUH between 2013 and 2023 for enrollment in the study.

Patients were classified into HL (34 patients) and NHL (41 patients) groups, and their clinical and outcome data were analysed separately to determine their distinct biological and treatment profiles, as shown in Table 1. A male predominance was evident in both subtypes. The mean age at diagnosis was 9 years for NHL patients and 10 years for HL patients.

Clinical data

The process of diagnosing lymphoma involves a thorough approach with imaging techniques such as whole-body CT scans, chest X-rays, and abdominal ultrasounds, when necessary, along with bone marrow and CSF aspirations (the latter only for NHL patients). As shown in Table 2, most NHL patients (31.7%) first presented with gastrointestinal (GI) symptoms, such as abdominal pain, masses, or signs of obstruction, whereas a majority of HL patients (70.6%) presented with neck masses. This difference in initial symptoms was statistically significant ($p = 0.003$). These distinct patterns in symptom presentation highlight the differing anatomical predilections and progression behaviors of HL and NHL in our cohort. Notably, the high proportion of abdominal symptoms in NHL patients may reflect diagnostic delays, particularly among patients referred from Gaza. Other symptoms observed included respiratory issues such as chronic cough and rarer signs such as facial swelling or jaw pain. At the time of diagnosis, NHL was mostly found at stage III (41.5%), whereas HL was more often diagnosed at stage II (41.2%), with fewer cases presenting at stage IV, where the disease had spread to bones, the CNS, or other organs. As shown in Table 3, subtype analysis revealed that BL (56.1%) was the most common subtype of NHL, whereas classical nodular sclerosing Hodgkin lymphoma (73.5%) was the most common subtype of HL, with these differences being statistically significant ($p < 0.001$). Immunohistochemistry was used to confirm specific markers for each subtype, ensuring accurate classification.

Outcome

Our study followed 75 pediatric lymphoma patients from diagnosis and during the completion of the treatment protocol to the last follow-up, with a mean value of 26.5 ± 18 months.

During the follow-up of each patient, regular PET scans or follow-up imaging, such as CT/MRI, were employed to identify relapse and remission. As shown in Fig. 1, most patients (65, 86.7%), including 29 HL (85.3%) patients and 36 NHL (87.8%) patients, experienced no events during follow-up. patients. Relapse occurred in 10 patients (13.3%), including 5 with HL and 5 with NHL.

The time to relapse ranged from 1 to 54 months, with a median of 8 months and a mean of 13 months. Among the patients who relapsed, 4 patients with HL achieved remission after retreatment, whereas none of the NHL patients achieved remission. Five patients (6.7%) remained in relapse after retreatment and were transferred for further care (1 HL, 4 NHL). This finding suggests a differential response to salvage regimens and may reflect more aggressive disease behavior in NHL patients. Since these patients experienced relapse before transfer, they were recorded as events in the EFS analysis. However, because they were still alive at their last follow-up, they were censored at the time of transfer in the OAS analysis via Kaplan–Meier survival curves. This ensures that their survival time contributed to the analysis without overestimating mortality.

Deaths occurred in 3 patients (4.0%), all from the NHL group, including 2 patients who died without preceding relapse and 1 patient who died after relapse; thus, 96% of all patients survived. Overall, 67 patients (89.3%), including 33 HL patients and 34 NHL patients, achieved remission. Total events (relapse or death) were slightly more common in NHL patients (7 patients) than in HL patients (5 patients), and in total, 12 events (relapse or death) were recorded. During the follow-up period (mean 26.5 ± 18 months), 84% of the patients experienced events (a total of 12 events, including relapse or death), with 86.7% of patients remaining event free. The 2-year event-free survival (EFS) rate was 85.1%, and the 2-year overall survival (OAS) rate was 96.6%, as estimated via Kaplan–Meier survival analysis, as shown in supplementary Figs. 1 and 2. These favourable short-term outcomes indicate effective protocol-based treatment despite systemic challenges, but longer follow-up is needed to assess late relapse and cure. The chi-square test was used to examine associations between patient

	Pediatric lymphoma($n = 75$) Frequency (%)	NHL($n = 41$) Frequency (%)	HL($n = 34$) Frequency (%)	*P* value
Age at diagnosis < 5 years 5–10 years ≥ 10 years	14 (18.7) 22 (29.3) 39 (52)	9 (22) 12 (29.3) 20 (48.8)	5 (14.7) 10 (29.4) 19 (55.9)	**0.704***
Gender Male Female Male: Female	46 (61.3) 29 (38.3) 1.6:1	27 (65.9) 14 (34.1) 1.9:1	19 (55.9) 15 (44.1) 1.3:1	**0.476***
Residence West Bank Gaza	42 (56) 33 (44)	21 (51.2) 20 (48.8)	21 (61.8) 13 (38.2)	**0.484***

Table 1. Demographics of pediatric lymphoma patients. * **Fisher's exact test**.

	NHL n (%) (*n* = 41)	HL *n* (%) (*n* = 34)	*P* value
Presentation			**0.003***
Neck mass	12 (29.3)	24 (70.6)	
Respiratory symptoms	8 (19.5)	2 (5.9)	
GI symptoms	13 (31.7)	3 (8.8)	
B symptoms	2 (4.9)	3 (8.8)	
Others*	6 (14.6)	2 (5.9)	
B symptoms			**0.109****
No	26 (63.4)	15 (44.1)	
yes	15 (36.6)	19 (55.9)	
Site			**0.018****
Head/neck	12 (29.3)	16 (47.1)	
mediastinal	5 (12.2)	10 (29.4)	
abdomen/pelvis	12 (29.3)	3 (8.8)	
Generalized	12 (29.3)	5 (14.7)	
BM involvement			**0.369***
no	37 (90.2)	33 (97.1)	
yes	4 (9.8)	1 (2.9)	
Stage			**0.999***
I	3 (7.3)	3 (8.8)	
II	16 (39)	14 (41.2)	
III	17 (41.5)	13 (38.2)	
IV	5 (12.2)	4 (11.8)	
Stage early/advanced			**0.819***
Early < 3	19 (46.3)	17 (50)	
Advanced ≥ 3	22 (53.7)	17 (50)	
LDH			**0.154****
Less than 320	17 (41.5)	21 (61.8))	
More than 320	13 (31.7)	5 (14.7)	
Not done	11 (26.8)	8 (23.5)	

Table 2. Clinical characteristics of pediatric lymphoma patients. ***Fisher exact test** ****Pearson chi square test**.

NHL	Frequency (*n* = 41) (%)	HL	Frequency (*n* = 34) (%)	*P* value
LL	13 (31.7)	Classical Nodular Sclerosing	25 (73.5)	**< 0.001**
DLBCL	5 (12.2)	Classical lymphocyte rich	4 (11.8)	
BL	23 (56.1)	Classical mixed cellularity	4 (11.8)	
ALCL	0	NLPHL	1 (2.9)	

Table 3. Histopathological findings of pediatric lymphoma. ***Pearson chi square test**. LL, lymphoblastic lymphoma; DLBCL, diffuse large B-cell lymphoma; BL, Burkitt's lymphoma; ALCL, anaplastic large-cell lymphoma; NLPHL, nodular lymphocyte predominant HL.

characteristics and treatment outcomes, and no significant correlations were found between demographic and clinical characteristics and survival or event rates, as shown in Supplementary Tables 1 and 2.

Additionally, Kaplan–Meier survival analysis was performed to compare EFS and OAS between HL patients and NHL patients. The log-rank test revealed nonsignificant differences between the groups ($p = 0.964$ and $p = 0.208$), as shown in Figs. 2 and 3. Censoring is indicated in the Kaplan–Meier curves, including for the five transferred patients in the OAS analysis.

Discussion

Our research on pediatric lymphoma in Palestine represents a pioneering effort, as no such study has been conducted before. Our primary objective was to investigate the clinical characteristics of HL and NHL patients and analyse their outcomes, emphasizing distinctions between the two.

Throughout our analysis, HL and NHL were evaluated as separate entities. Comparisons made are descriptive and not inferential.

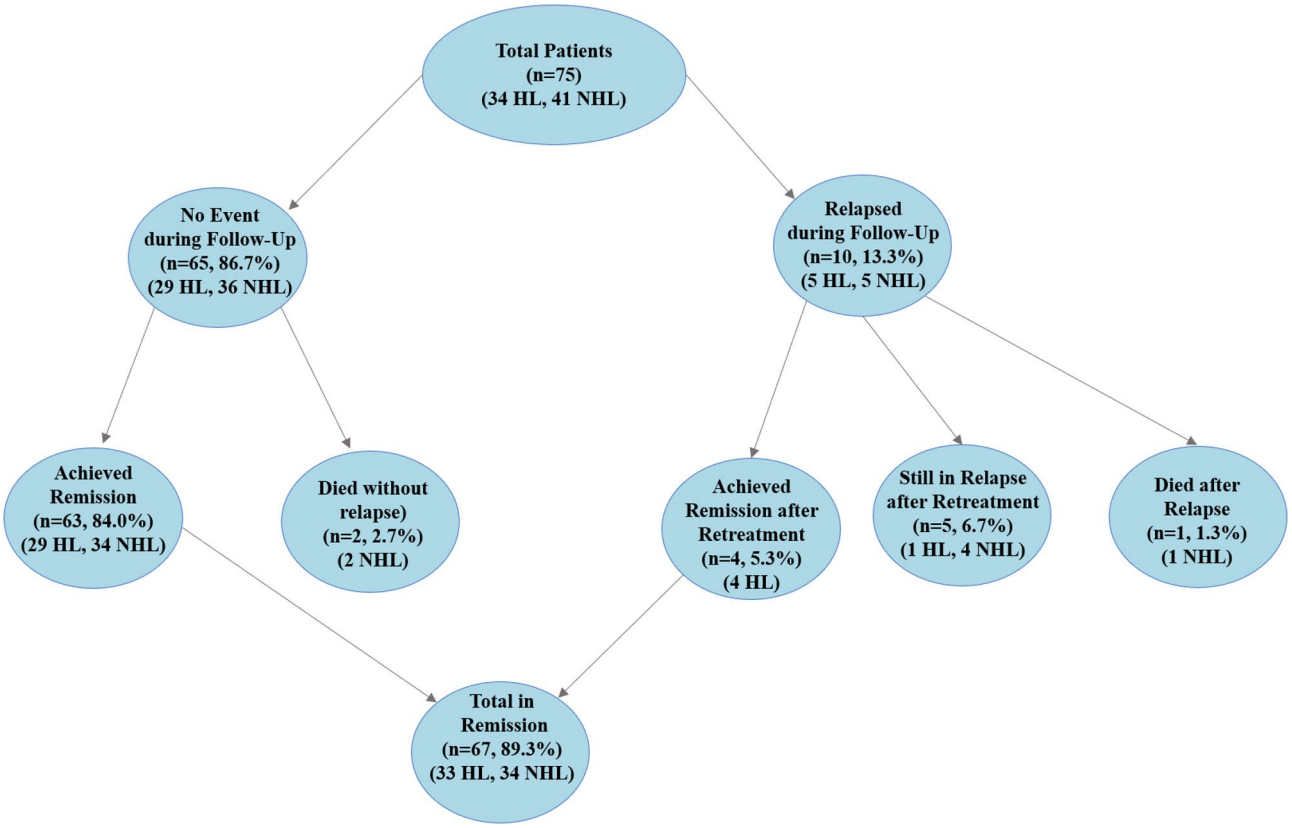

Fig. 1. Treatment outcomes of pediatric lymphoma patients.

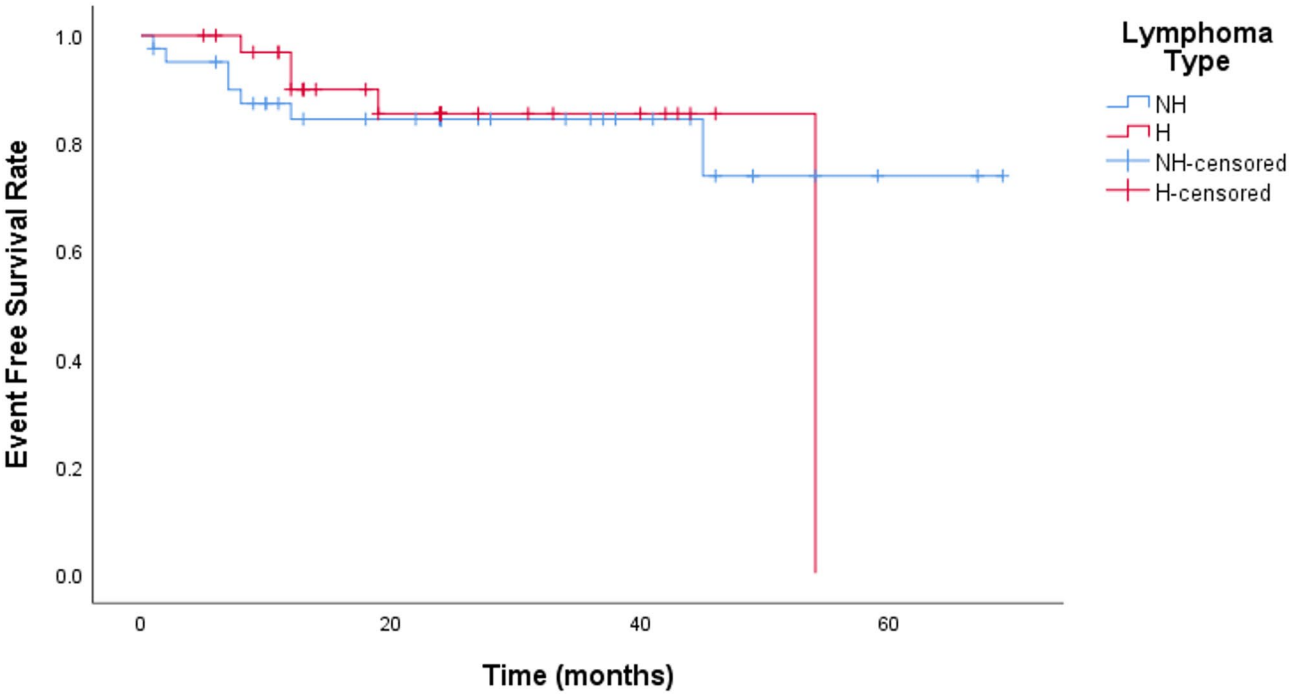

Fig. 2. Kaplan–Meier curve for event-free survival (EFS) in HL patients vs. NHL patients. No statistically significant difference was observed ($P = 0.964$, log-rank test). Mean event-free survival was 55.75 months (95% CI: 48.74-62.76).

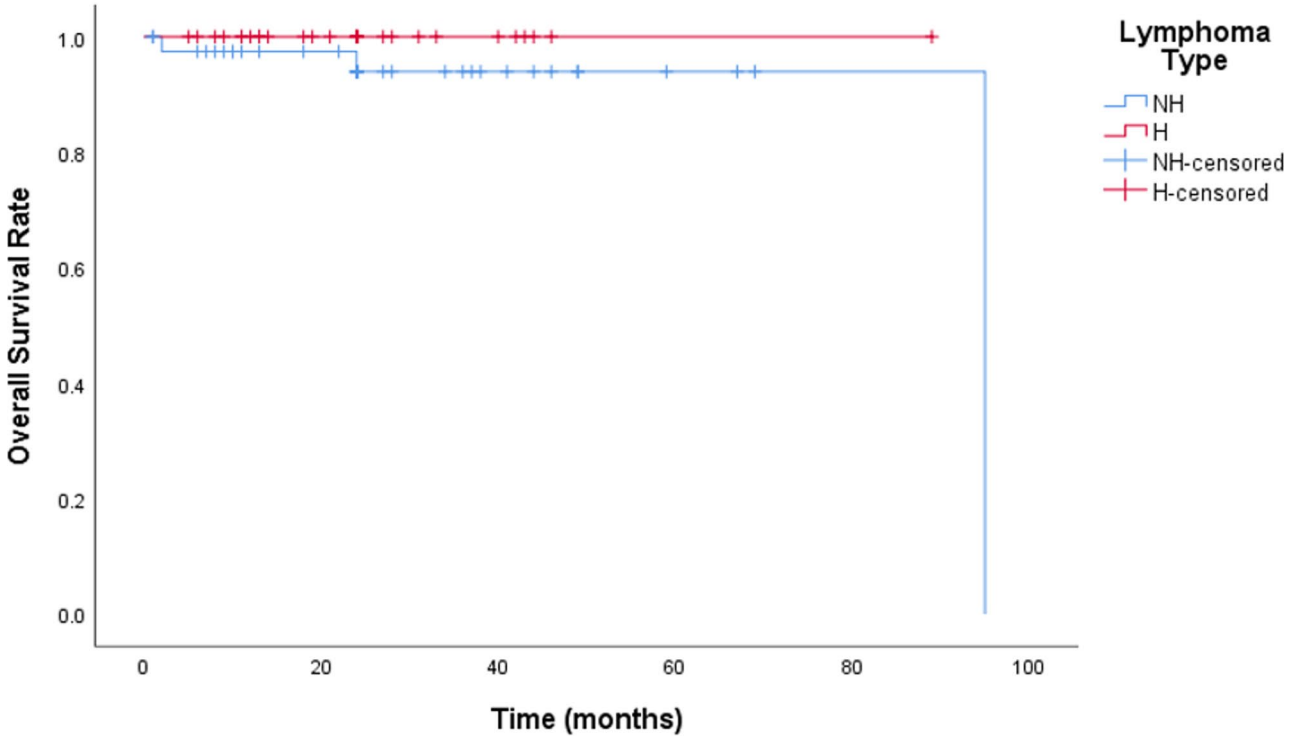

Fig. 3. Kaplan–Meier curve for overall survival (OAS) in HL patients vs. NHL patients. No statistically significant difference was observed ($P = 0.208$, log-rank test).

Among both HL and NHL patients, males presented a greater prevalence, which aligns with findings from global research studies conducted in Egypt, Korea, the United States, East Asia, Saudi Arabia, and Turkey[21–26]. Notably, the male-to-female ratio in our study was approximately 2:1 for both HL and NHL, whereas in the aforementioned studies, it was commonly reported as 2.5:1, 3:1, or 4.5:1.

In our study, individuals aged > 10 years emerged as the predominant age group affected by pediatric lymphoma, a trend consistent with findings from research conducted in Korea and the USA[21,23]. In contrast, studies in Turkey and India reported a higher prevalence among those aged < 5 years, whereas in Egypt, the (5–10 years) age category stood out[22,26,27].

Notably, countries exhibiting a predominance of younger age groups are often associated with a higher prevalence of Epstein–Barr virus (EBV), which is thought to be linked to a younger age of presentation. These regional variations underscore the complex interplay between age demographics and potential viral factors influencing the incidence of pediatric lymphoma[22,28].

BL has consistently emerged as the most common pathological subtype of NHL, which aligns with other global investigations[21,24,26,29]. Conversely, HL exhibited variability in the most frequent pathological subtype across studies. Our research and studies in Egypt and the USA consistently identified classical nodular sclerosing as predominant[22,30]. Conversely, studies conducted in the UK and India reported that the mixed cellularity type was the most dominant[27,31].

In terms of initial presentation, abdominal manifestations such as abdominal masses or abdominal signs/symptoms such as intestinal obstruction predominated in NHL patients, which is consistent with studies in other countries[32]. HL patients predominantly present with neck masses or masses.

The tumor's primary site, which is the primary region of disease concentration or origin, was identified with equal frequency as the most predominant site in three regions—the head and neck, abdomen and pelvis—and generalized in NHL. In a study conducted in Thailand, it was in the head and neck region, and in Korea, the Prague Czech Republic and Turkey, it was mainly in the abdomen[21,26,29,33].

In our study, the majority of patients diagnosed with NHL presented with an advanced stage (≥ stage 3) at the time of diagnosis (53.7%). Conversely, in the HL group, there was an equal distribution, with 50% of patients diagnosed with early-stage disease (< stage 3) and the remaining 50% with advanced-stage disease (≥ stage 3). Interestingly, the literature commonly reports diagnoses of both HL and NHL at advanced stages[21,22,24,27,29].

B symptoms were more common in HL patients (55.9%) than in NHL patients (36.6%). This finding was consistent with the literature in the case of NHL, whereas some studies on HL reported that the majority of patients had B symptoms, and others reported that the majority had no B symptoms[22,27].

In addition to these clinical characteristics, region-specific factors also shaped the presentation and outcomes in our cohort. A notable distinction in our cohort is the high proportion of patients from Gaza (44%), where access to care is often limited. In addition to geographic and political barriers, the Gaza Strip has endured repeated episodes of armed conflict over the past decade, which have significantly disrupted healthcare services.

These conditions likely contribute to delays in diagnosis, treatment interruption, and loss to follow-up, ultimately affecting disease progression and outcomes for paediatric lymphoma patients in this region. Furthermore, fluctuations in chemotherapy drug availability and limited access to advanced imaging or pathology tools can restrict the use of guideline-recommended protocols. Additionally, neck masses, as predominant HL symptoms and gastrointestinal symptoms for NHL, were more pronounced in our cohort than typically reported. These differences may reflect diagnostic delays and region-specific disease patterns. These challenges not only affect early detection and treatment completion but also limit the feasibility of standardized follow-up and national protocol implementation. Addressing these barriers is essential for improving long-term outcomes and establishing equity in pediatric cancer care across regions of Palestine.

In terms of our outcomes, the survival of children and adolescents with cancer has clearly significantly increased over time[34]. For children under 15 years of age, the OAS rate increased to 90% for NHL[35,36] and 98% for HL[37]. According to American Cancer Society estimates, the OASs for HL and NHL were 99% and 91%, respectively, for children younger than 14 years. Compared with 98% and 89%, respectively, for children between 15 and 19 years of age[11].

In our study, the survival rate for pediatric lymphoma patients was 96% on the basis of the survival outcome of the last hospital follow-up; 100% of HL patients and 92.7% of NHL patients survived. Similar to a study performed in Bangladesh, a total of 76.5% of patients survived; 100% of HL patients and 60% of NHL patients survived[38].

In our study, relapses were observed in 9 patients, accounting for 12% of all lymphoma patients; 5 (14.7% of those with HL) and 4 (9.8% of those with NHL) of the 5 patients with HL. The EFS rate for paediatric lymphoma patients was 85.1%. Studies performed in Thailand, Korea, and East Asia among NHL pediatric patients reported similar results (71.5% ± 4.3%, 67.7 ± 8.0%, and 84%, respectively, for 5-year EFS[21,24,29].

We found no significant associations between OAS or EFS and disease stage ($p = 0.35$ and $p = 0.34$, respectively). These findings diverge from those of prior studies, which often reported significant associations[22,39]which might be due to the small sample size of our study or the early transfer of advanced stages, which were excluded from the study.

Two studies performed in East Asia and Spain reported that initial LDH levels were significantly associated with OAS and EFS and that higher LDH values were associated with poorer outcomes[18,24]. Our study, however, had no significant p value for that association (0.999).

Although the study period spans 10 years, the mean follow-up duration was 26.5 months. Therefore, OS and EFS were calculated as short-term outcomes and should not be interpreted as long-term survival indicators.

Study limitations

The study's limitations include the small sample size of 75 pediatric lymphoma patients, which may limit the ability to identify significant treatment changes or generalize findings. Although NNUH is a main referral center, some pediatric lymphoma cases in Gaza and the southern West Bank may have been treated at other institutions. Access to records from those centers was limited due to logistical and administrative barriers.

Additionally, the retrospective design of this study, encompassing data collected from 2013–2023, introduces inherent constraints, including potential inconsistencies in data recording and variations in follow-up durations. Patient inclusion and follow-up periods varied due to factors such as treatment completion without subsequent follow-up or transfer to specialized facilities. Notably, some patients completed their prescribed treatment regimens but did not return for scheduled follow-up assessments, limiting the ability to monitor long-term outcomes and assess sustained remission or potential late relapses. Additionally, five patients transferred to other centers were alive at their last follow-up; however, their posttransfer outcomes remain unknown, limiting the comprehensiveness of our survival analysis. Moreover, logistical and geographic challenges, particularly for patients from the Gaza Strip, limit our ability to conduct the longer-term follow-up necessary to assess cure rates. The mean follow-up duration of 26.5 ± 18 months was insufficient to evaluate long-term outcomes definitively. The limited follow-up duration was largely due to logistical and political barriers that restrict long-term access to care, especially for patients from Gaza, who often cannot return for extended monitoring. Additionally, inconsistent outpatient surveillance, incomplete follow-up records, and the absence of a centralized cancer registry contributed to the constrained follow-up window. These systemic challenges limit our ability to assess long-term outcomes and cure rates. Determining 'cure' in pediatric lymphoma patients typically requires a follow-up period of five years or more to monitor for late relapse and sustained remission. The relatively short follow-up in this study precludes the assessment of cure rates and may lead to the underestimation of late-occurring events.

To mitigate these limitations, future research should consider prospective study designs with standardized data collection methods and extended follow-up periods. Such approaches would enable a more accurate assessment of long-term outcomes, including cure rates, and provide a clearer understanding of the factors influencing survival and remission in paediatric lymphoma patients.

Our 10-year study of pediatric lymphoma patients at NNUH provided valuable insights into their demographics and clinical characteristics, highlighting the success of their treatment protocols. However, it also highlights the need for improved cancer registries and a nationwide association for patients to improve communication and care quality.

Conclusions

Our study provides insights into the clinical characteristics and short-term outcomes of pediatric lymphoma patients in Palestine. Pediatric lymphoma is more common in males and primarily affects children over 10 years of age. HL is less prevalent, has a higher survival rate, and most commonly presents with a neck mass. In

contrast, NHL is more common, is associated with higher relapse and mortality rates, and often presents with gastrointestinal symptoms. Burkitt's lymphoma (BL) is the most common NHL subtype and is not strongly associated with B symptoms. These findings emphasize the importance of early diagnosis and continuous follow-up in optimizing treatment outcomes. However, owing to the small sample size and limited follow-up duration, long-term conclusions cannot be drawn. Further studies with larger cohorts and extended follow-up are needed to validate these findings and assess long-term survival and cure rates.

Data availability

The data supporting the findings of this study are available upon request from the corresponding authors. The datasets used in this study were analyzed using SPSS software. For access to the data, please contact Dania Abu-halima at dabuhalima@gmail.com.

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Author contributions
DA, DM, and ZQ collected and analyzed the data and prepared the initial draft of the manuscript under the supervision of AAT and SM. AAT, SZ and SM provided critical revisions and DA finalized the manuscript. All authors reviewed and approved the final version of the manuscript for submission.

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Declarations

Competing interests
The authors declare no competing interests.

Ethics approval and consent to participate
Due to the retrospective nature of this study, the need to obtain informed consent was waived by the An-Najah National University Institutional Review Board (Approval number: Med. Oct. 2023/111) and the Clinical Research Committee of An-Najah National University Hospital (Approval number: CRC_2023_0160). The study was conducted using pre-existing, de-identified data, and ethical approval was obtained before initiating the research.

Additional information
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