



Anemia at Diagnosis in Pediatric Solid Tumors: Prevalence, Severity, and Hematologic Patterns: A Single-center Retrospective Study

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Abstract

Introduction Anemia is a frequent clinical finding at the time of diagnosis in children with solid tumors and may reflect tumor biology, nutritional status, or bone marrow involvement. However, the pattern and severity of anemia across different solid tumor types in children remain underreported.

Objective The aim of this study was to evaluate the prevalence and characteristics of anemia at presentation among pediatric patients with various solid tumors.

Materials and Methods This retrospective observational study included 149 children with newly diagnosed solid tumors, aged 0 to 18 years. Anemia was classified based on the World Health Organization age-specific hemoglobin thresholds and further categorized into mild, moderate, and severe grades. Tumors were classified into bone tumors, central nervous system (CNS) tumors, abdominal tumors, soft tissue sarcomas, germ cell tumors, and others. Associations between anemia and tumor type were analyzed using descriptive statistics and chi-square tests.

Results Anemia was present in 67 (45%) patients at diagnosis. Bone tumors detected in 52 patients (34.9%) and CNS tumors detected in 34 patients (22.8%) were the most common malignancies. Among those with anemia, 36.4% had mild, 45.5% moderate, and 18.2% severe anemia. Statistical analysis revealed a significant association between red cell indices (mean corpuscular volume, mean corpuscular hemoglobin [MCH], red cell distribution width [RDW], mean corpuscular hemoglobin concentration) and anemia status ($p < 0.001$), with low MCH and high RDW suggesting the anemia was predominantly microcytic and hypochromic, with substantial anisocytosis.

Conclusion Anemia is a common presenting feature in pediatric solid tumors. Detailed investigations to delineate the etiology of anemia are necessary to guide targeted management of the tumor as well as to correct the anemia.

Keywords

- ▶ anemia
- ▶ prevalence
- ▶ red cell indices
- ▶ pediatric

Introduction

Anemia is a common comorbidity in patients with malignancies, with an incidence as high as 90% in adults and may serve as a surrogate marker for disease burden and reduced quality of life.¹ While anemia is well documented in pediatric hematological malignancies, there are limited data on its prevalence, patterns, and severity in pediatric solid tumors at presentation, with reported rates between 20 and 74%. The reason for anemia at presentation in children with solid tumors can result from a multitude of factors, including chronic inflammation, bone marrow infiltration, blood loss, and nutritional deficiencies.^{2,3} However, most studies focus on anemia during the course of therapy rather than diagnosis. The current study aims to assess the prevalence, severity, and hematological characteristics of anemia at the time of diagnosis in children with solid tumors.

Materials and Methods

Study Design and Setting

This retrospective cross-sectional study was conducted in the department of pediatric oncology at a tertiary care center in South India. All pediatric patients diagnosed with solid tumors between January 2020 and December 2024 were included. The sample size was determined by the total number of eligible patients diagnosed during the study period, and no prior sample size calculation was performed, as this was a retrospective analysis.

Inclusion Criteria

- Children aged 0 to 18 years.
- Histologically or radiologically confirmed diagnosis of a solid tumor.
- Availability of complete blood count at initial presentation before the initiation of therapy.

Exclusion Criteria

- Patients with hematological malignancies.
- Patients with incomplete hematologic records at presentation.
- Patients who had received any blood transfusion prior to initial presentation and blood sample collection (i.e., before inclusion in the study).

Objectives

- To determine the prevalence and severity of anemia at diagnosis among pediatric patients with solid tumors.
- To analyze the association between anemia and tumor type, age group, and gender.
- To assess the red cell indices mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and red cell distribution width (RDW), and characterize the hematological patterns of anemia.
- To evaluate the prevalence and characteristics of anemia in children with advanced-stage/metastatic solid tumors.

Outcomes

Primary Outcome

- Prevalence of anemia at diagnosis in pediatric solid tumors, as defined by the World Health Organization (WHO) age-specific hemoglobin cutoffs.

Secondary Outcomes

- Distribution of anemia severity (mild, moderate, severe) by tumor type, age, and gender.
- Characterization of hematologic indices (MCV, MCH, MCHC, RDW) associated with anemia.
- Prevalence and severity of anemia in children with advanced-stage or metastatic solid tumors.

Data Collection

Demographic profile (age, gender, tumor type, stage/risk, presence or absence of metastasis) and hematological parameters (hemoglobin, red cell indices [MCV, MCH, MCHC, RDW], and peripheral smear findings) were retrieved from electronic medical records and laboratory information system. Anemia was diagnosed and classified into mild, moderate, and severe based on WHO criteria for age-appropriate hemoglobin cutoffs.⁴

Statistical Analysis

Data were analyzed using Jamovi v2.6.44 (The Jamovi Project, Sydney, Australia). Descriptive statistics were used to summarize demographic and clinical variables. The prevalence of anemia was expressed in proportions. Associations between anemia and hematologic parameters were tested using chi-square tests for categorical variables and Mann-Whitney's *U*-tests for continuous variables. A *p*-value of <0.05 was considered statistically significant.

Ethical Approval

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki (1960). Ethical approval was obtained from the Institutional Ethics Committee of Kasturba Medical College, Manipal (IEC No.: 693/2023). As this was a retrospective study using anonymized data, the requirement for informed consent was waived.

Results

Prevalence of Anemia

Out of 181 pediatric patients with solid tumors initially screened, 149 met the inclusion criteria and were analyzed, while 32 were excluded due to incomplete hemogram data, prior transfusion, or relapse. The median age at diagnosis was 8 years, with a slight male predominance. Bone tumors and central nervous system (CNS) tumors were the most common diagnoses, together constituting more than half of the cohort. This pattern is consistent with the tumor distribution typically observed in pediatric oncology at tertiary care centers in India (► **Table 1**).

Table 1 Demographic profile

Variable	Category	N (%)
Age group	6 mo to <2 y	22 (14.8)
	2–5 y	38 (25.5)
	6–11 y	40 (26.8)
	12–14 y	23 (15.4)
	> 14 y	26 (17.4)
Sex	Female	68 (45.6)
	Male	81 (54.4)
Diagnosis type	Bone tumors	52 (34.9)
	CNS tumors	34 (22.8)
	Abdominal tumors	23 (15.4)
	Soft tissue sarcomas	16 (10.7)
	GCT	13 (8.7)
	Other tumors	11 (7.4)
Anemia status	Yes	67 (45)
	No	82 (55)

Abbreviations: CNS, central nervous system; GCT, germ cell tumor.

Nearly half of the children are presented with anemia at diagnosis, with moderate anemia being the predominant pattern. Younger children (<5 years) and females were more frequently affected, suggesting possible age- and sex-related susceptibility (►Table 2).

Moderate anemia emerged as the most frequent category across tumor groups, while severe anemia was relatively uncommon. Abdominal and bone tumors showed the greatest burden of moderate-to-severe anemia, in contrast to CNS tumors, where most children had only mild anemia. These patterns highlight the tumor-type-specific variation in anemia severity (►Fig. 1).

Hematologic Indices and Anemia

Significant differences were observed in red blood cell indices between anemic and nonanemic patients ($p < 0.01$). Of 67

Table 2 Anemia characteristics and prevalence

Parameter	Category/subgroup	N (%)
Age group	6 mo to <2 y	16/67 (23.9)
	2–5 y	21/67 (31.3)
	6–11 y	11/67 (16.4)
	12–14 y	11/67 (16.4)
	> 14 y	8/67 (11.9)
Sex	Female	42/67 (62.7)
	Male	25/67 (37.3)
Anemia severity	Mild	22/67 (32.8)
	Moderate	37/67 (55.2)
	Severe	8/67 (11.9)

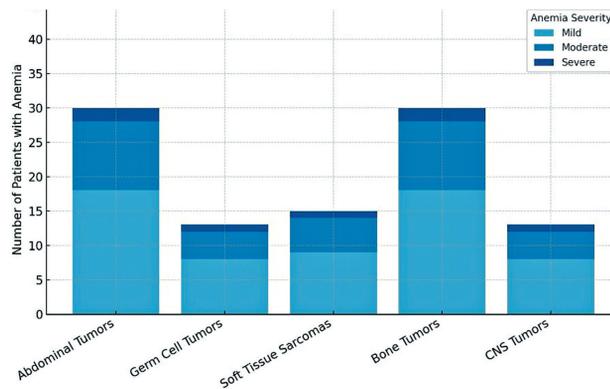


Fig. 1 Prevalence and severity of anemia disease-wise. CNS, central nervous system.

Table 3 Comparison of RBC indices—anemic versus nonanemic patients

RBC index	Anemic (mean ± SD)	Nonanemic (mean ± SD)
MCV (fL)	72.4 ± 6.1	82.6 ± 5.9
MCH (pg)	22.1 ± 2.5	27.8 ± 2.3
MCHC (g/dL)	30.5 ± 1.8	32.5 ± 1.5
RDW (%)	17.8 ± 2.1	13.2 ± 1.7

Abbreviations: MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; MCV, mean corpuscular volume; RBC, red blood cell; RDW, red cell distribution width; SD, standard deviation.

anemic individuals, 37 (55.2%) have low MCV, low MCH, and high RDW altogether, suggesting the anemia was predominantly microcytic and hypochromic, with significant anisocytosis in affected patients (►Table 3).

Anemia in Advanced Disease

In a subgroup of 39 pediatric patients with Stage 3, Stage 4, or metastatic solid tumors (excluding neuroblastoma and rhabdomyosarcoma, which are known to involve bone marrow), 23 (59%) were anemic. Anemia was more common in the advanced-stage cohort compared with the overall cohort (59 vs. 45%). Bone tumors accounted for 35.9% ($n = 14$) of this group, with eight patients presenting with anemia. Among the anemic cases in this cohort, 8 (34.8%) had mild anemia, 13 (56.5%) had moderate anemia, and 2 (8.7%) had severe anemia. Disease-wise anemia prevalence in advanced solid tumors is detailed in ►Table 4.

Discussion

Anemia at presentation was observed in nearly half of pediatric patients with solid tumors in this study. This aligns with prior reports that estimate anemia prevalence between 51 and 74% in pediatric oncology patients at diagnosis.^{2,5} Contributing factors may include chronic inflammation,

Table 4 Prevalence of anemia in advanced cancer

Diagnosis	Prevalence of anemia, N (%)
Abdominal tumors	6/6 (100)
Bone tumors	8/14 (57)
CNS tumors	0/6 (0)
GCT	3/4 (75)
Soft tissue sarcomas	6/8 (75)
Other tumors	0/1 (0)

Abbreviations: CNS, central nervous system; GCT, germ cell tumor.

nutritional deficiencies, bone marrow suppression, and tumor-related blood loss. Notably, this prevalence is lower than that observed in the general pediatric population. According to the National Family Health Survey (NFHS-5, 2019–21), the prevalence of anemia among children aged 6 to 59 months in India is 67.1%, with moderate-to-severe anemia comprising a significant portion of the burden.⁶

The observed anemia was primarily microcytic and hypochromic, as indicated by significantly lower MCV and MCH values. The markedly elevated RDW in anemic patients suggests anisocytosis due to ineffective erythropoiesis or iron-restricted conditions possibly reflecting anemia of chronic disease or iron deficiency anemia.^{5,7,8} This phenotype contrasts with normocytic anemia typically seen in acute or hemolytic conditions.

Moderate anemia was the most prevalent, particularly in children with abdominal tumors (19.4%), bone tumors (11.9%), and germ cell tumors (GCTs) (9.0%). While only two cases of tumor rupture were documented, the high prevalence of moderate anemia in abdominal tumors may suggest subclinical blood loss or chronic inflammation. However, direct evidence of gastrointestinal or intratumoral bleeding was not consistently documented, and this hypothesis warrants further prospective evaluation.

Bone tumors also had the highest number of severe anemia cases (6.0%), suggesting a greater systemic impact or possible marrow involvement. In contrast, localized GCT and soft tissue sarcomas were predominantly associated with mild-to-moderate anemia, possibly due to lower marrow suppression or systemic inflammatory load.

This tumor-type-specific distribution emphasizes the need for tailored supportive care strategies, including timely nutritional assessment and correction of iron or micronutrient deficiencies, intravenous iron therapy in selected cases, use of erythropoiesis-stimulating agents where appropriate, and proactive monitoring in high-risk groups, such as those with abdominal or advanced-stage tumors.

Anemia is highly prevalent (59%) in children with advanced-stage and metastatic solid tumors (excluding those known to involve the bone marrow), particularly in bone tumors, abdominal tumors, and metastatic soft tissue sarcomas. Most cases were moderate in severity, suggesting chronic disease-related anemia, blood loss (tumor rupture). The absence of anemia in CNS tumors highlights the variation in anemia risk based on tumor type and biology. These

findings underscore the need for early anemia screening and supportive care in high-risk groups within the advanced disease population.

Strengths

One of the few Indian studies assessing anemia at diagnosis in pediatric solid tumors, with a relatively large cohort and use of the WHO criteria for consistency.

Generalizability

Findings reflect patterns seen in similar tertiary care settings in India and are broadly comparable to international data, making them relevant to other low- and middle-income countries.

Gray Areas

Lack of iron studies, inflammatory markers, and nutritional markers limited the ability to identify specific anemia subtypes.

Future Research

Prospective multicenter studies with detailed etiologic work-up and evaluation of treatment outcomes are needed to strengthen evidence and guide supportive care.

Conclusion

Anemia was present in nearly half of pediatric solid tumor cases at diagnosis, with higher prevalence in younger children, females, and those with abdominal or advanced-stage tumors. The hematologic profile, predominantly microcytic and hypochromic anemia suggests iron-restricted erythropoiesis. While this cross-sectional study cannot assess causality or clinical outcomes, these findings highlight the need for anemia screening and context-specific supportive care at diagnosis. Prospective studies incorporating iron studies and long-term follow-up are warranted to better define the etiologic and prognostic implications of anemia in this population.

Authors' Contributions

V.B.K. conceptualized and designed the study and contributed to manuscript preparation and editing. S.P.M. contributed to the literature search, data acquisition, data analysis, manuscript preparation, and editing. A.M. was involved in data acquisition and analysis. N.S. contributed to data analysis and statistical analysis. A.M.V., E.A.R., S.B., and S.L.K. provided intellectual input and reviewed the manuscript. All authors have contributed to the manuscript in significant ways and have reviewed and agreed upon the manuscript content.

Patient Consent

Consent waiver was obtained from IEC as this was a retrospective study.

Conflict of Interest

None declared.

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