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Original Article

Analysis of transfusion practices and efficacy in pediatric acute leukemia: a single-center study

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ABSTRACT

This article aims to analyze current red blood cell (RBC) transfusion practices and evaluate the efficacy and safety of different transfusion thresholds in patients with pediatric acute leukemia (AL) at a single center. Clinical data from 220 children with AL who received RBC transfusions at the Third Xiangya Hospital of Central South University between January 1 and December 31, 2023, were retrospectively collected. Patients were divided into three groups based on pre-transfusion hemoglobin (Hb) levels: a low Hb group (≤ 60 g/L, n = 43), a medium Hb group (61–70 g/L, n = 137), and a high Hb group (> 70 g/L, n = 40). Basic clinical characteristics, Hb increment (ΔHb), anemia symptom improvement rate, and incidence of transfusion-related adverse reactions were compared among the groups. The median pre-transfusion Hb threshold was approximately 66 g/L across all subgroups based on age, disease subtype, presence of co-existing infection, or anemia symptoms, with no statistically significant differences observed among the groups (P > 0.05). No significant differences were identified among the three groups regarding transfusion dose or ΔHb (median: 15 g/L, 16 g/L, and 17 g/L, respectively; P = 0.581). Among the 55 children with pre-transfusion anemia symptoms, symptom improvement rates also showed no significant differences among the three groups (P > 0.05). The overall incidence of transfusion-related adverse reactions was 0.91% (2/220), with no differences among the groups. The results suggest that RBC transfusions effectively increase Hb levels and alleviate symptoms across different threshold groups, with a good safety profile. No clear association was observed between transfusion thresholds and efficacy or safety.

Keywords: acute leukemia, children, red blood cell transfusion, transfusion threshold, hemoglobin, efficacy, safety

INTRODUCTION

Acute leukemia (AL) is fundamentally a malignant clonal disorder of hematopoietic stem and progenitor cells[1–2]. In recent years, rapid advancements in combination chemotherapy, molecular targeted

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therapy, immunotherapy, and hematopoietic stem cell transplantation technology have significantly improved the complete remission rate and long-term disease-free survival rate of pediatric AL[3–5]. However, through the disease course and its intensive treatment, normal bone marrow hematopoiesis is severely suppressed, inevitably leading most children to develop varying degrees of anemia, thrombocytopenia, and neutropenia. This makes transfusion support therapy an indispensable and critical component of the overall treatment strategy for pediatric AL[6].

The optimal hemoglobin (Hb) threshold for red blood cell (RBC) transfusions in anemic patients remains an active area of research. Blood is a limited resource, and transfusion is associated with recognized risks[7–8]. Beyond the well-known risks of transfusion-transmitted diseases and allergic reactions, RBC transfusion in children with leukemia may lead to complications such as alloimmunization, transfusion-associated graft-versus-host disease (TA-GVHD), iron overload, and potential immuno-modulatory effects, all of which may impact subsequent treatment and long-term prognosis[9–12].

Hb level is a primary determinant for transfusion[13]. However, research specifically addressing transfusion in pediatric hematology-oncology patients remains limited. Most current pediatric transfusion guidelines concerning transfusion thresholds are extrapolated from studies in adults, lacking high-quality evidence derived from pediatric populations[14]. Therefore, this study aims to retrospectively analyze the clinical transfusion data of children with AL admitted to our hospital, systematically investigate transfusion practices, and comprehensively evaluate transfusion efficacy and safety. The overarching goal is to provide valuable clinical evidence for optimizing transfusion strategies, facilitating individualized and precise transfusion support and improving the prognosis of children with AL.

SUBJECTS AND METHODS

Data sources

The data were sourced from the medical records of children diagnosed with AL who received transfusion therapy at the Third Xiangya Hospital of Central South University between January 1 and December 31, 2023. A total of 220 patients were enrolled in the study. This study was approved by the Ethics Committee of the Third Xiangya Hospital of Central South University (Approval No. 25972).

Inclusion and exclusion criteria

The inclusion criteria were as follows: (1) diagnosis of AL according to standard criteria; (2) age ≤ 16 years; (3) receipt of transfusion therapy during hospitalization. Exclusion criteria included: (1) incomplete clinical data; (2) critically ill patients in the terminal stage of disease; (3) comorbid chronic non-hematological conditions; (4) pre-existing cardiac disease; (5) presence of unexpected RBC antibodies.

Outcome measures and data collection

Basic clinical data collected included demographic characteristics (age, weight, and gender) and disease-related characteristics (leukemia subtype: acute lymphoblastic leukemia [ALL] or acute myeloid leukemia [AML]; current chemotherapy status; presence of complications). For each RBC transfusion event, the following indicators were recorded in detail: Hb level within 24 hours prior to transfusion; presence of anemia-related symptoms (*e.g.*, pallor, fatigue, palpitations, tachypnea); post-transfusion Hb level (24–48 hours after administration); and assessment of whether anemia symptoms had resolved. The occurrence of transfusion-related adverse reactions (including allergic reactions, febrile non-hemolytic reactions, hemolytic reactions, *etc*.) and the occurrence of nosocomial infections post-transfusion were also recorded.

Grouping criteria

First, a descriptive analysis was performed on all RBC transfusion events, focusing on the actual transfusion triggers (represented by pre-transfusion Hb levels) in different clinical contexts. Statistical analysis and comparisons were conducted across subgroups based on age (0–3 years, 4–6 years, 7–12 years, and 12–15 years), disease subtype (ALL *vs*. AML), presence of pre-transfusion anemia symptoms, and presence of co-existing infection. Second, to further evaluate the efficacy and safety of different transfusion thresholds, using a single RBC transfusion event as the unit of analysis, children were divided into three groups according to their pre-transfusion Hb level: Group I (Hb ≤ 60 g/L), Group II (60 g/L < Hb ≤ 70 g/L), and Group III (Hb > 70 g/L). Third, clinical characteristics (including age, disease subtype, weight, chemotherapy status, and infection status) were compared among the three groups to assess their comparability. Further comparisons were conducted regarding transfusion efficacy indicators, including Hb increment (ΔHb = post-transfusion Hb − pre-transfusion Hb), post-transfusion Hb target achieve-

ment rate, and anemia symptom relief rate. Regarding safety, the incidence of nosocomial infections was compared among the three groups. Finally, the overall incidence of transfusion-related adverse reactions, as well as the variations in specific types, was summarized and compared.

Statistical analysis

Statistical analysis was performed using GraphPad Prism 8 software. Measurement data were presented as mean ± standard deviation ($\bar{x}$ ± s), and between-group comparisons were conducted using the *t*-test or one-way analysis of variance (ANOVA). Enumeration data were presented as percentages (%), and between-group comparisons were conducted using the chi-square test. A $P < 0.05$ was considered statistically significant.

RESULTS

Pre-transfusion Hb levels across pediatric patient groups

This study visualized and compared the distribution of pre-transfusion Hb levels across pediatric patients with AL based on different clinical characteristics using box plots. Across the age groups (0–3 years, 3–6 years, 7–12 years, and 13–15 years), the median pre-transfusion Hb levels were relatively similar at 66 g/L, 65 g/L, 67 g/L, and 65 g/L, respectively. Analysis of variance showed no significant differences between the groups ($P = 0.1389$) (***Fig. 1***).

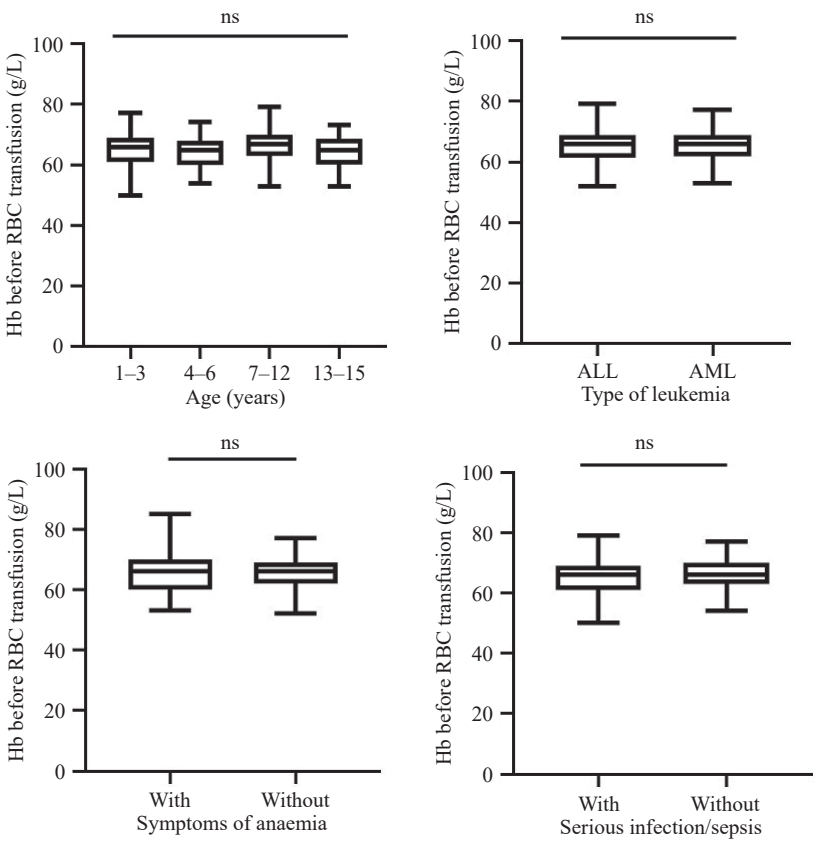

Fig. 1 **Pre-transfusion hemoglobin (Hb) levels in different pediatric populations.** RBC: red blood cell; ns: not significant; ALL: acute lymphoblastic leukemia; AML: acute myeloid leukemia.

When comparing disease types, the median pre-transfusion Hb level was 66 g/L (interquartile range, IQR: 61.5–69 g/L) in children with ALL and 66 g/L (IQR: 62–69 g/L) in those with AML, with no statistically significant difference between the two groups ($P = 0.7360$) (***Fig. 1***).

No significant differences in Hb thresholds for transfusion decisions were observed based on the presence of pre-transfusion anemia symptoms (symptomatic group median: 66 g/L *vs*. asymptomatic group: 66 g/L, $P = 0.8990$) or the presence of co-existing infections (infection group median: 66 g/L *vs*. non-infection group: 66 g/L, $P = 0.2249$) (***Fig. 1***).

Comparison of clinical characteristics among different threshold groups

To evaluate the efficacy of RBC transfusions in pediatric patients with different transfusion

thresholds, this study included 220 children with AL. They were divided into three groups based on their pre-transfusion Hb levels: a low Hb group (≤ 60 g/L, n = 43), a medium Hb group (61–70 g/L, n = 137), and a high Hb group (> 70 g/L, n = 40). All transfused RBC components in this study were leukocyte-reduced. The basic clinical characteristics of the three groups were compared to assess intergroup comparability, as shown in ***Table 1***.

No statistically significant differences were found among the groups in terms of gender, age, or leukemia subtype (ALL/AML) (P > 0.05). Regarding complications, the incidence of severe infection or sepsis was 76.7%, 62.0%, and 57.5% in the three groups, respectively. Although a trend toward lower incidence was noted in the high Hb group, the intergroup difference did not reach statistical significance (P = 0.1356).

Table 1 **Comparison of clinical characteristics among different threshold groups**

Characteristics	Hb level groups			Statistical value	P value
	≤ 60 g/L	61–70 g/L	> 70 g/L		
Number of patients	43	137	40		
Gender					
Male [n (%)]	25 (58.1)	100 (73.0)	29 (72.5)	3.584	0.1666
Female [n (%)]	18 (41.9)	37 (27.0)	11 (27.5)		
Age (years)	8.4 ± 4.7	8.8 ± 4.3	9.1 ± 4.2	0.242	0.7854
Diagnosis					
ALL [n (%)]	30 (69.8)	85 (62.0)	25 (62.5)	0.871	0.6469
AML [n (%)]	13 (30.2)	52 (38.0)	15 (37.5)		
Infection					
Infection or sepsis [n (%)]	33 (76.7)	85 (62.0)	23 (57.5)	3.996	0.1356

Hb: hemoglobin; ALL: acute lymphoblastic leukemia; AML: acute myeloid leukemia.

Assessment of transfusion efficacy

Hb increment

A stratified analysis was performed based on pre-transfusion Hb levels to investigate the influence of anemia severity on transfusion efficacy (***Table 2***). All pediatric patients were categorized into three groups: Hb ≤ 60 g/L (n = 43), Hb 61–70 g/L (n = 137), and Hb > 70 g/L (n = 40). The results demonstrated that the RBC transfusion dose was comparable across the three groups (median: 1.5 U for all, P = 0.217 for intergroup comparison). Although post-transfusion Hb levels increased in all groups, the difference in ΔHb among the three groups was not statistically significant (P = 0.581), with median ΔHb values of 15 g/L, 16 g/L, and 17 g/L, respectively. Therefore, the data from this study indicated no clear correlation between pre-transfusion Hb levels and the absolute post-transfusion Hb increase in this patient cohort.

Table 2 **Transfusion parameters and efficacy among different pre-transfusion Hb groups**

Hb level groups	≤ 60 g/L (n = 43)	61–70 g/L (n = 137)	> 70 g/L (n = 40)	Statistical value	P value
Absolute transfusion dose (U)					
Median, IQR	1.5 (1.0–2.0)	1.5 (1.0–2.0)	1.5 (1.5–2.0)	1.541	0.2166
Pre-transfusion Hb (g/L)					
Median, IQR	57.0 (55.0–59.0)	66.0 (64.0–68.0)	73.5 (72.0–76.8)		
Post-transfusion Hb (g/L)					
Median, IQR	71.0 (65.0–77.0)	82.0 (76.5–90.0)	94.0 (85.0–97.0)		
ΔHb (g/L)					
Median, IQR	15.0 (9.0–21.0)	16.0 (10.0–24.5)	17.0 (7.3–22.8)	0.545	0.5808

Hb: hemoglobin; IQR: interquartile range, ΔHb: Hb increment.

Anemia symptom improvement

The pre-transfusion prevalence of anemia-related symptoms (including dizziness, fatigue, loss of appetite, shortness of breath, tachycardia, and hypotension) was comparable across the three groups (***Table 3***). Among the 220 enrolled children, 55 (25.0%) presented with at least one anemia-related symptom before transfusion. The proportion of symptomatic children was highest in the ≤ 60 g/L group (34.9%, 15/40), followed by the > 70 g/L group (32.5%, 13/40) and the 61–70 g/L group (19.7%, 27/137). However, the differences in pre-transfusion symptom prevalence were not statistically significant (P = 0.0644).

Table 3 **Comparison of pre-transfusion anemic symptoms among the three pediatric groups**

Hb level groups	Number of patients	With symptoms [*n* (%)]	Without symptoms [*n* (%)]	*P* value
≤ 60 g/L	43	15 (34.9)	28 (65.1)	0.0644
61–70 g/L	137	27 (19.7)	110 (80.3)	
> 70 g/L	40	13 (32.5)	27 (67.5)	
Total	220	55 (25.0)	165 (75.0)	

Hb: hemoglobin.

This study analyzed symptom improvement in children with pre-transfusion anemia symptoms (n = 55) after RBC transfusion. As shown in ***Table 4***, after excluding asymptomatic children prior to transfusion, the symptom improvement rates in Group I, Group II, and Group III were 73.3% (11/15), 66.7% (18/27), and 61.5% (8/13), respectively. The differences among the three groups were not statistically significant (P = 0.195).

Table 4 **Comparison of post-transfusion symptom improvement among the three groups of children with anemia symptoms**

Hb level groups	Symptomatic children (*n*)	Improved after transfusion (*n*)	Improvement rate (%)	*P* value
Group I (≤ 60 g/L)	15	11	73.3	0.7990
Group II (61–70 g/L)	27	18	66.7	
Group III (> 70 g/L)	13	8	61.5	
Total	55	37	67.3	

Hb: hemoglobin.

Assessment of transfusion safety

A total of 2 transfusion-related adverse reactions were observed among the enrolled patients, representing an overall incidence of 0.91% (2/220). One case of allergic reaction (manifesting as pruritus and urticaria) occurred in Group I, and one case of febrile non-hemolytic transfusion reaction was reported in Group II. No statistically significant difference in the incidence of adverse reactions was detected among the three groups (P > 0.05), likely due to the low overall event rate.

DISCUSSION

This single-center retrospective study analyzed transfusion practices and outcomes in 220 pediatric patients with AL. Our findings indicate that there were no significant intergroup differences in transfusion thresholds across age groups, disease subtypes, or clinical conditions. Nevertheless, the distribution of Hb levels within each subgroup showed considerable variation, suggesting that transfusion decisions in clinical practice may be influenced by a combination of individualized factors rather than by any single clinical characteristic alone. In summary, the three groups were comparable in terms of major baseline characteristics. Furthermore, among the collected cases, some transfusion thresholds deviated from guideline recommendations, with patients receiving RBC transfusions at Hb levels greater than 70 g/L. The reasons are likely multi-faceted, potentially including the physician's thorough evaluation, variations in clinicians' interpretation of transfusion guidelines, and parental preferences.

In the evaluation of transfusion efficacy, no significant differences in ΔHb were observed among the three threshold groups despite variations in baseline Hb levels. This finding suggests that varying transfusion thresholds did not significantly influence the rate of short-term symptom improvement following RBC transfusion. The observed numerical trend in improvement rates may be attributed to factors such as underlying disease status, co-existing infections, and the subjectivity of symptom assessment. This implies that the absolute post-transfusion Hb increase may be influenced more by transfusion dose or patient-specific factors such as blood volume and erythropoietic reserve, rather than by the initial severity of anemia. Moreover, improvement in anemia-related symptoms did not differ significantly among the groups, although there was a non-significant trend toward greater symptom relief in the lower Hb group. This may be attributable to the multifactorial nature of symptom presentation in leukemic children, where factors such as infection, metabolic status, and chemotherapy-related toxicity could confound the assessment of anemia-related symptoms. Additional research involving larger sample sizes is necessary to validate these findings.

Regarding safety, the overall incidence of transfusion-related adverse reactions was low (0.91%), consistent with previous reports and

underscoring the relative safety of current leukocyte-reduced blood products in preventing common transfusion complications in immunocompromised pediatric patients[15].

Several limitations of this study should be acknowledged. First, its retrospective, single-center design may limit the generalizability of the findings. Second, the sample size, particularly in the extreme Hb groups, was relatively small, which may have reduced the statistical power to detect significant differences in secondary outcomes such as symptom improvement and infection rates. Third, the assessment of anemia symptoms relied on clinical documentation, which is subjective and potentially inconsistent. Additionally, the clinical data included were limited. For example, the absence of information on hepatosplenomegaly, a recognized site of extravascular hemolysis, precluded a comprehensive evaluation of its potential role as a confounding factor in transfusion efficacy. Furthermore, without individual body weight data for the pediatric patients, it was not possible to calculate the precise transfusion dose (mL/kg) standardized by weight, which may affect the assessment of transfusion dose adequacy.

Despite these limitations, this study provides evidence supporting the safety and comparable efficacy of a moderate transfusion threshold (approximately 60–70 g/L) in pediatric AL patients. Future prospective, multicenter studies with larger sample sizes and standardized symptom assessment tools are warranted to refine transfusion strategies and establish evidence-based guidelines tailored to this vulnerable population.

Author contributions

Conceptualization, Rong Huang and Peiyun Gan; Methodology, Rong Huang; Software, Sijie Wu; Validation, Rong Huang, Sijie Wu, and Peiyun Gan; Formal Analysis, Peiyun Gan; Investigation, Peiyun Gan; Resources, Zhihua Deng; Data Curation, Zhihua Deng; Writing – Original Draft Preparation, Zhihua Deng; Writing – Review & Editing, Fang Wei; Visualization, Zhihua Deng; Supervision, Fang Wei; Project Administration, Fang Wei.

Ethics statement

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of the Third Xiangya Hospital of Central South University (Approval No. 25972).

Informed consent statement

This study did not contain any identifiable information. Patient consent was waived.

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Declaration of competing interest

The authors declared no conflict of interests.

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