Original Article

Anthropometric and Nutritional Status of Children with Transfusion-Dependent β-Thalassemia: Transfusion Characteristics and Iron Burden in a North Indian Cohort

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Abstract

Background: Growth impairment and undernutrition remain important concerns in children with transfusion-dependent β-thalassemia (TDT). Regular transfusion improves anemia but is accompanied by progressive iron loading, making simultaneous assessment of growth, transfusion adequacy, and iron burden important. The objective is to evaluate the anthropometric and nutritional status of children with TDT and evaluate their transfusion profile, iron burden, treatment characteristics, and relationships among age, pretransfusion hemoglobin, and serum ferritin. **Material and Methods:** This prospective observational study was conducted at the Thalassemia Day Care Centre of Pt. B.D. Sharma Post Graduate Institute of Medical Sciences, Rohtak. One hundred children aged 2–14 years who had been receiving regular red-cell transfusions every 2–3 weeks for at least one year were enrolled. Demographic, anthropometric, clinical, transfusion-related, treatment, and laboratory variables were prospectively recorded. Continuous variables were summarized as mean ± standard deviation and categorical variables as number and percentage. Pearson correlation coefficients were used to assess relationships among age, duration of regular transfusion, transfusion interval, pretransfusion hemoglobin, and serum ferritin. **Results:** The mean age was 8.60 ± 3.80 years; 56% were male and 84% had thalassemia major. Sixteen children (16%) were underweight, 82% had a normal BMI, and 2% were overweight. Mean pretransfusion hemoglobin was 5.20 ± 1.60 g/dL, mean transfusion interval was 21.80 ± 5.20 days, and mean serum ferritin was 1,892 ± 1,377 ng/mL. Ferritin correlated positively with age (r=0.31, p=0.002) and duration of regular transfusion (r=0.34, p<0.001), and inversely with transfusion interval (r=-0.25, p=0.010). Chelation therapy was documented in 64% of participants. **Conclusion:** Underweight affected approximately one in six children with TDT, while overweight was uncommon. Higher serum ferritin was associated with older age, longer duration of regular transfusion, and shorter transfusion intervals. These findings support regular growth surveillance together with optimization of transfusion therapy, serial iron monitoring, and individualized chelation.

Keywords: β-thalassemia; children; anthropometry; nutritional status; serum ferritin; blood transfusion; iron chelation.

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Introduction

β-thalassemia is an inherited disorder characterized by reduced or absent synthesis of beta-globin chains, resulting in ineffective erythropoiesis, chronic hemolytic anemia, and varying degrees of disease severity. Children with transfusion-dependent β-thalassemia (TDT) require regular red-cell transfusions, usually from early childhood, to maintain adequate hemoglobin levels, suppress ineffective erythropoiesis, and support normal growth and development.[1] The disease is particularly common in the Mediterranean region, the Middle East, South Asia, and Southeast Asia, although migration has made it a global health problem.[2] Despite improvements in treatment and survival, thalassemia continues to contribute substantially to childhood morbidity.[3] India has a high disease burden, with a recent systematic review estimating a pooled β-thalassemia carrier prevalence of approximately 3.7% in the general population.[4]

Regular red-cell transfusion has greatly improved the survival and quality of life of children with TDT. However, repeated transfusions lead to progressive iron accumulation because the body has no effective physiological mechanism for removing excess iron. Over time, iron deposition can affect the liver, heart, endocrine organs, and bones.[5] Optimal management therefore requires adequate transfusion, regular assessment of iron burden, appropriate chelation therapy, and monitoring of growth and endocrine function.[6] Maintaining an appropriate pretransfusion hemoglobin is particularly important during childhood, when chronic anemia may adversely affect growth

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and development.[7]

Growth and nutritional problems in children with TDT are multifactorial. Chronic anemia, inadequate nutritional intake, increased metabolic requirements, iron overload, liver dysfunction, endocrine abnormalities, delayed puberty, and factors related to chelation therapy may all contribute to impaired growth.[8] Body mass index (BMI) is simple and useful for routine nutritional assessment, but BMI alone may not identify reduced lean body mass, altered body composition, or impaired linear growth.[9] Regular assessment of weight, height, BMI, growth pattern, pubertal development, dietary intake, and relevant micronutrients is therefore important in long-term care.[10]

Data evaluating nutritional status together with transfusion characteristics and iron burden remain limited in many Indian pediatric thalassemia services. Therefore, this prospective study was conducted in a pediatric TDT cohort in North India to assess age-specific anthropometric parameters and BMI categories; describe transfusion characteristics, pretransfusion hemoglobin, serum ferritin, and treatment profiles; and examine relationships among age, duration of regular transfusion, transfusion interval, pretransfusion hemoglobin, and serum ferritin.

Materials and Methods

Study Design and Setting: This prospective observational study was conducted over a period of one year in the Department of Pediatrics, in collaboration with the Department of Immunohaematology and Blood Transfusion, at Pt. B.D. Sharma Post Graduate Institute of Medical Sciences (PGIMS), Rohtak, India. Children were recruited from the institutional Thalassemia Day Care Centre. Demographic, anthropometric, clinical, transfusion-related, treatment, and laboratory parameters were prospectively recorded at enrollment.

Participants: The study included 100 children aged 2–14 years with β-thalassemia diagnosed on the basis of clinical findings and high-performance liquid chromatography. Children who had been receiving regular red-cell transfusions every 2–3 weeks for at least one year were eligible. Children with diagnoses other than β-thalassemia, those not receiving regular transfusions, those receiving systemic corticosteroids or other immunosuppressive therapy, and those whose parents or legal guardians did not provide consent were excluded.

Data Collection and Measurements: Demographic data included age, sex, state of origin, family history of thalassemia, and family history of blood transfusion. Clinical and transfusion-related variables included thalassemia phenotype, age at diagnosis, age at first transfusion, duration of regular transfusion, average pretransfusion hemoglobin, average transfusion interval, serum ferritin, chelation therapy, fetal-hemoglobin-inducing therapy, and history of splenectomy.

Anthropometric assessment was performed at enrollment. Weight was recorded in kilograms and height in centimeters. Children were grouped as 2–5, 6–10, and 11–14 years. Nutritional status was assessed using the BMI-for-age categories recorded in the study data: underweight below the 5th percentile, normal BMI from the 5th to 85th percentile, and overweight above the 85th percentile.

Serum ferritin was used as a routinely available indicator of iron burden. Ferritin may be influenced by inflammation and is not equivalent to direct assessment of organ iron by magnetic resonance imaging.

Study Outcomes: The primary outcome was anthropometric and nutritional status assessed using age-specific weight, height, and BMI categories. Secondary analyses described selected transfusion and iron-status characteristics and examined correlations among age, duration of regular transfusion, transfusion interval, pretransfusion hemoglobin, and serum ferritin.

Statistical Analysis: Continuous variables were expressed as mean ± standard deviation and range, where available, and categorical variables as numbers and percentages. Student's t test was used for continuous comparisons between thalassemia major and transfusion-dependent thalassemia intermedia. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. Pearson correlation coefficients were used to assess relationships among age, duration of regular transfusion, transfusion interval, pretransfusion hemoglobin, and serum ferritin. All tests were two-sided, and $p<0.05$ was considered statistically significant.

Ethical Considerations: The study was approved by the Institutional Ethics Committee of PGIMS, Rohtak. Written informed consent was obtained from parents or legal guardians before enrollment. Patient confidentiality was maintained throughout the study.

Results

All 100 enrolled children were included. The mean age was 8.60 ± 3.80 years (range, 2–14 years); 39% were aged 6–10 years, 32% were aged 11–14 years, and 29% were aged 2–5 years. Males constituted 56% of the cohort. Thalassemia major was the predominant phenotype (84%), while 16% had transfusion-dependent thalassemia intermedia.

Table 1: Baseline characteristics of the cohort (N=100)

Characteristic	Value
Age, years	8.60 ± 3.80 (range 2-14)
Age 2-5 years	29 (29.00)
Age 6-10 years	39 (39.00)
Age 11-14 years	32 (32.00)
Male sex	56 (56.00)
Female sex	44 (44.00)
Thalassemia major	84 (84.00)
Transfusion-dependent thalassemia intermedia	16 (16.00)

Mean weight and height increased across the three age groups, from 13.50 ± 2.80 kg and 95.20 ± 10.10 cm at 2–5 years to 34.70 ± 6.20 kg and 145.60 ± 13.50 cm at 11–14 years. Overall, 16 children were underweight, 82 had a normal BMI, and two were overweight. The proportion underweight was 17.24% at 2–5 years, 17.95% at 6–10 years, and 12.50% at 11–14 years (Table 2).

Table 2: Age-stratified anthropometric characteristics and BMI categories of the study population

Age group	n	Weight, kg	Height, cm	Underweight	Normal BMI	Overweight
2-5 years	29	13.50 ± 2.80	95.20 ± 10.10	5 (17.24)	24 (82.76)	0 (0.00)
6-10 years	39	22.40 ± 4.50	120.80 ± 12.30	7 (17.95)	31 (79.49)	1 (2.56)
11-14 years	32	34.70 ± 6.20	145.60 ± 13.50	4 (12.50)	27 (84.38)	1 (3.13)
Overall	100	-	-	16 (16.00)	82 (82.00)	2 (2.00)

Weight and height are mean ± standard deviation; BMI categories are n (% within age group). Underweight: BMI-for-age <5th percentile; normal: 5th–85th percentile; overweight: >85th percentile.

Selected transfusion and iron-status characteristics are summarized in [Table 3].

Table 3: Selected transfusion and iron-status characteristics

Characteristic	Overall (N=100)
Duration of regular transfusion, years	5.90 ± 3.50
Pretransfusion hemoglobin, g/dL	5.20 ± 1.60
Transfusion interval, days	21.80 ± 5.20
Serum ferritin, ng/mL	1,892 ± 1,377
Chelation therapy	64 (64.00)

Chelation therapy was documented in 64 children (64%).

Correlation analysis showed a strong relationship between age and duration of regular transfusion (r=0.92, p<0.001). Higher serum ferritin was associated with older age (r=0.31, p=0.002), longer duration of regular transfusion (r=0.34, p<0.001), and shorter transfusion interval (r=-0.25, p=0.010). Longer transfusion intervals showed a weak positive correlation with pretransfusion hemoglobin (r=0.22, p=0.030). The inverse correlation between ferritin and pretransfusion hemoglobin was not statistically significant (r=-0.18, p=0.070) [Table 4]. These correlations describe transfusion and iron-status relationships and do not directly test an association between BMI and ferritin.

Table 4: Pearson correlation matrix for age, transfusion characteristics, hemoglobin, and ferritin

Variable	Age	Transfusion duration	Transfusion interval	Hemoglobin	Ferritin
Age	1.00	0.92 (<0.001)	-0.15 (0.140)	0.05 (0.620)	0.31 (0.002)
Transfusion duration	-	1.00	-0.13 (0.200)	0.03 (0.760)	0.34 (<0.001)
Transfusion interval	-	-	1.00	0.22 (0.030)	-0.25 (0.010)
Hemoglobin	-	-	-	1.00	-0.18 (0.070)
Ferritin	-	-	-	-	1.00

Discussion

In this prospective pediatric TDT cohort, 16% of children were underweight, whereas overweight was uncommon. The cohort also showed a substantial iron burden, with mean serum ferritin close to 1,900 ng/mL, and chelation therapy was documented in 64%. Higher ferritin was associated with older age, longer duration of regular transfusion, and shorter transfusion intervals. These findings highlight two important clinical concerns in children receiving long-term transfusion therapy: nutritional vulnerability and progressive iron accumulation.

The 16% prevalence of BMI-defined underweight in our study was lower than the broader malnutrition prevalence reported in some previous pediatric thalassemia studies. Biswas et al. reported malnutrition in 48.2% of children with β-thalassemia major in Kolkata,[11] while a Turkish study reported malnutrition in 20.99% of transfusion-dependent children.[12] Direct comparison should be made cautiously because studies have used different definitions of nutritional impairment, and some include stunting, wasting, or other anthropometric measures in addition to BMI.

A normal BMI does not necessarily indicate normal growth or body composition. Previous studies have reported short stature, reduced lean mass, and micronutrient deficiencies in children with thalassemia even when BMI was not markedly abnormal.[13] BMI is therefore useful as a screening measure but should be interpreted together with serial height, growth velocity, pubertal development, dietary assessment, and other indicators of nutritional status.

Serum ferritin increased with age and with longer duration of regular transfusion in our cohort. This is consistent with progressive iron exposure over time. Previous studies examining the relationship between ferritin and growth have produced variable results.[14,15] Importantly, present study did not directly compare individual BMI or other anthropometric indices with ferritin. We therefore cannot conclude that iron overload caused underweight in this cohort. Serum ferritin is also affected by inflammation and does not directly measure hepatic or cardiac iron.[16]

The inverse relationship between transfusion interval and ferritin should also be interpreted cautiously. Children requiring

transfusions at shorter intervals may have greater transfusion dependence and therefore greater red-cell exposure. However, the observed correlation does not mean that shorter transfusion intervals themselves cause iron overload. Total transfused units, red-cell volume per kilogram, annual red-cell requirement, chelation adherence, and inflammatory status would be needed for a more complete assessment of transfusional iron loading.

The mean pretransfusion hemoglobin in this cohort was 5.20 g/dL, which is low for children receiving regular transfusions. The observed pretransfusion hemoglobin levels highlight the importance of regularly assessing transfusion adequacy, including transfusion dose, interval, red-cell requirement, and hemoglobin trends over time. Adequate transfusion is essential for suppressing ineffective erythropoiesis and supporting normal growth and development in children with TDT.[6,7]

Chelation therapy was documented in 64% of participants. This finding highlights the importance of evaluating iron burden and chelation practices in this population rather than assuming that every child not documented on chelation necessarily met treatment indications. Chelation should be individualized according to transfusion exposure, iron burden, treatment tolerance, and adherence. Regular monitoring is important because both inadequate control of iron overload and excessive chelator exposure may affect long-term outcomes.[21–24]

From a clinical perspective, growth assessment should be integrated into routine transfusion care. Serial weight, height, BMI-for-age, and growth velocity should be recorded, with pubertal assessment when age appropriate. Children with falling growth centiles, persistently low pretransfusion hemoglobin, rising ferritin, or concerns about chelation adherence should undergo more detailed nutritional and endocrine evaluation. Where available, ferritin trends should be complemented by organ-specific iron assessment and appropriate endocrine testing.[25–28]

Strengths and Limitations: The strengths of this study include its prospective design, inclusion of 100 children from a dedicated thalassemia day-care service, and systematic collection of anthropometric, clinical, transfusion, treatment, and iron-status variables. However, the study was conducted at a single center and did not include a healthy comparison group. BMI alone may not identify stunting, reduced muscle mass, altered body composition, or micronutrient deficiency. Direct patient-level analyses linking anthropometric indices with ferritin and transfusion variables were not available in the present dataset. Serum ferritin may be influenced by inflammation and is not equivalent to organ iron measured by magnetic resonance imaging. Information on total transfused units or volume, annual red-cell requirement, dietary intake, socioeconomic status, chelation adherence, pubertal stage, endocrine investigations, and organ-specific iron measurements was also unavailable. These limitations restrict assessment of the determinants of impaired growth and prevent causal interpretation of the observed correlations.

Conclusion

In this pediatric TDT cohort, 16% of children were underweight and only 2% were overweight. Higher serum ferritin was associated with older age, longer duration of regular transfusion, and shorter transfusion intervals. Chelation therapy was documented in fewer than two thirds of participants. These findings highlight the need to integrate longitudinal growth surveillance with optimization of transfusion therapy, serial assessment of iron burden, and individualized chelation. Future prospective studies incorporating standardized anthropometric indices, dietary assessment, endocrine evaluation, and organ-specific iron measurements are needed to better define the factors associated with impaired growth in children with TDT.

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Conflicts of interest

There are no conflicts of interest.

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