

HEMATOLOGICAL PROFILE OF CHILDREN WITH SEVERE ACUTE MALNUTRITION-A CROSS SECTIONAL STUDY

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ABSTRACT

Background: Severe acute malnutrition (SAM) disturbs haematopoiesis, but hospital data from southern India remain limited. This study assessed the haematological profile of children with SAM at a rural medical college hospital in Tiruvannamalai, Tamil Nadu. **Materials and Methods:** A prospective study enrolled 100 children with SAM defined by World Health Organization criteria, recruited from the inpatient, outpatient and emergency departments of a government medical college hospital between February 2024 and February 2025. Complete blood count, peripheral smear and micronutrient assays were performed. Chi-square and t-tests were applied, with alpha set at 0.05. **Result:** Of the study participants, 44 were female and 46 were male; 63 were aged 6–23 months, and 62 were from rural areas. Marasmus was present in 65 children, kwashiorkor in 19, and marasmic kwashiorkor in 16. Anaemia was present in 51 children, including 28 (54.9%) with mild, 19 (37.3%) with moderate, and 4 (7.8%) with severe anaemia. Microcytic anaemia was predominant (28, 54.9%), followed by dimorphic anaemia (16, 31.4%); morphology did not differ by sex ($\chi^2 = 0.20$, $p = 0.98$). Children aged >24 months had five-fold higher odds of anaemia (odds ratio 5.05, 95% confidence interval 1.91–13.32, $p = 0.001$). Ferritin, folic acid, and vitamin B12 levels were comparable between sexes, whereas haemoglobin, haematocrit, mean corpuscular volume, mean corpuscular haemoglobin concentration, and neutrophil percentage differed significantly. **Conclusion:** Anaemia affected half the cohort and was predominantly microcytic. Age above 24 months carried the strongest association, supporting age-targeted screening and supplementation.

INTRODUCTION

Severe acute malnutrition (SAM) remains one of the most lethal forms of undernutrition in early childhood. The 2025 joint estimates of UNICEF, the World Health Organization and the World Bank place the number of children under five affected by wasting in 2024 at 42.8 million, or 6.6% of the age group, of whom 12.2 million (1.9%) were severely wasted.^[1] SAM is defined by a weight-for-height z score below -3 standard deviations, a mid-upper arm circumference below 115 mm in children aged 6 to 59 months, or bilateral pitting oedema, criteria carried forward in the 2023 World Health Organization guideline on the prevention and management of wasting and nutritional oedema.^[2] The 2021 update of the Lancet Series on maternal and child undernutrition showed that wasting and stunting frequently coexist, affecting 4.7% of

children in low-income countries simultaneously, a combination associated with a 4.8-fold increase in mortality, and that the incidence of both peaks within the first six months of life.^[3]

India carries a large share of this burden. The National Family Health Survey-5 recorded wasting in 19.3% of children under five and severe wasting in 7.7%.⁴ Distribution within the country is uneven. Tamil Nadu, which performs comparatively well on most health indices, still reports severe wasting in 6.8% of children under five,^[4] while the predominantly rural district of Tiruvannamalai records 9.2%.^[5] Districts of this kind are easily overlooked when state-level figures appear reassuring.

Anaemia is the commonest complication of SAM and a substantial burden in its own right. The Global Burden of Disease Study 2021 estimated the global prevalence of anaemia at 24.3%, corresponding to

1.92 billion prevalent cases, with children younger than five among the groups most affected; dietary iron deficiency alone accounted for the largest share of anaemia-related years lived with disability.^[6] How anaemia is defined has itself come under review: haemoglobin fifth centiles derived from eight international datasets in 2024 were 104.4 g/L at 6 to 23 months and 110.2 g/L at 24 to 59 months, which questions the use of a single 110 g/L threshold across the whole preschool age range.^[7]

The causes of anaemia in a malnourished child are rarely single. Inadequate dietary iron, folate and vitamin B12 deficiency, chronic inflammation, parasitic infection and impaired erythropoiesis from marrow hypoplasia all contribute,^[8,9] and morphology follows the underlying deficiency, so anaemia in SAM may be normocytic normochromic, microcytic hypochromic, macrocytic, or dimorphic where deficiencies coexist.^[9] Recent Indian data underline how often deficiencies combine: among 100 children aged 6 to 59 months with SAM, vitamin B12 deficiency was present in 61% and folate deficiency in 19%.^[10] Leukocyte and platelet abnormalities occur alongside. Leukopenia may follow marrow suppression or sepsis-induced depletion, while leukocytosis often signals infection that the blunted inflammatory response of a malnourished child would otherwise conceal.^[11] Bone marrow studies in severe protein-energy malnutrition have shown erythroid hypoplasia, megaloblastic and dysplastic change, and absent marrow iron in most cases.^[9] Deficiencies of iron, zinc, copper, folate and vitamin A act directly on DNA synthesis, erythropoiesis and immune function,^[12-14] while subclinical inflammation and environmental enteric dysfunction are increasingly implicated in poor growth and impaired iron handling.^[3] Inflammation also complicates measurement: in preschool children, adjusting serum ferritin for C-reactive protein and α 1-acid glycoprotein changed estimates of iron deficiency prevalence by a median of 25 percentage points.^[15] Hospital-based data describing the haematological spectrum of SAM in southern India remain scarce, and most published work relies on small samples, limited haematological detail, or community rather than hospital populations. Because the pattern of malnutrition and its complications varies between regions and between care settings, local data are needed to guide clinical management and supplementation programmes.^[16] The present study was undertaken to evaluate the haematological abnormalities of children admitted with SAM to a government medical college hospital serving a rural district of Tamil Nadu, and to examine their relationship with demographic, clinical and biochemical characteristics.

MATERIALS AND METHODS

Study design and setting: This was a prospective observational study conducted over one year, from

February 2024 to February 2025, at Government Tiruvannamalai Medical College and Hospital, Tiruvannamalai, Tamil Nadu. Children with SAM presenting to the inpatient and outpatient departments of Paediatrics and the Department of Emergency Medicine were screened during the study period. Children who fulfilled the eligibility criteria were enrolled, giving a total sample of 100 children.

Inclusion and Exclusion criteria

Eligible children were those aged 6 months to 5 years, of either sex, who fulfilled the World Health Organization criteria for severe acute malnutrition and whose parents or guardians provided informed consent.

Children were excluded if they had mild or moderate malnutrition, chronic illness, a history suggestive of ongoing haemolysis or haemoglobinopathy, had received haematinics, including iron, vitamin B12 or folic acid, within three months before admission, or had received a blood transfusion within four months before admission.

Procedure: After obtaining informed written consent from the parent or guardian, relevant socio-demographic, clinical, feeding and treatment-related information was recorded at admission. These included age, sex, residence, exclusive breastfeeding, immunisation status, diarrhoea, fever, oedema, age at introduction of complementary feeding, meat consumption, milk intake, type of SAM, and prior administration of antibiotics, folic acid and vitamin A.

Peripheral venous blood was collected for complete blood count. Haemoglobin concentration was used to identify anaemia and to grade its severity as mild (10–10.9 g/dL), moderate (7–9.9 g/dL) or severe (<7 g/dL). A peripheral blood smear was examined to classify the morphological type of anaemia as microcytic, macrocytic, normocytic or dimorphic.

Serum ferritin, folic acid and vitamin B12 levels were estimated as biochemical parameters. Haematological parameters including red blood cell count, haematocrit, mean corpuscular volume, mean corpuscular haemoglobin, mean corpuscular haemoglobin concentration, red cell distribution width, total leukocyte count, neutrophil percentage, lymphocyte percentage and platelet count were recorded and compared between male and female children.

The association of anaemia with age group, sex, residence, exclusive breastfeeding, type of SAM, antibiotic administration, folic acid supplementation and vitamin A supplementation was assessed. Morphological types of anaemia were also compared according to sex, and biochemical and haematological parameters were compared between male and female children.

Statistical Analysis: Data were entered in Microsoft Excel and analysed using IBM SPSS Statistics version 22.0 (IBM Corp., Armonk, NY, USA). Categorical variables were expressed as numbers and percentages, while continuous variables were expressed as mean $\pm$ standard deviation. The chi-

square test was used to assess associations between categorical variables. Welch's independent-samples t-test was used to compare continuous variables between male and female children. Univariate logistic regression was performed to estimate crude odds ratios (ORs) with 95% confidence intervals (CIs) for factors associated with anaemia. A two-sided p value <0.05 was considered statistically significant, and a 95% CI was used throughout.

Ethical considerations: Ethics committee approval was obtained from the Institutional Ethics Committee of Government Tiruvannamalai Medical College and Hospital. Informed written consent was obtained from the parents or guardians of all participants before enrolment (ECR/1364/INST/TN/2020). The ethical principles of beneficence and justice were followed throughout the study.

RESULTS

One hundred children with SAM were enrolled; 54 were female and 46 male. Eight were aged <6 months, 63 were aged 6–23 months, and 29 were ≥2 years. Sixty-two children were from rural areas and 38 from urban areas. Exclusive breastfeeding during the first six months was reported in 75 children. Immunisation was incomplete in 44 children, complete in 19, absent in 4, and unknown in 33. Diarrhoea and pneumonia were present in 37 and 39 children, respectively. Marasmus accounted for 65 cases, kwashiorkor for 19, and marasmic kwashiorkor for 16. Antibiotics, folic acid, and vitamin A had been given to 43, 53, and 87 children, respectively [Table 1].

Table 1: Socio-demographic characteristics of children with severe acute malnutrition (n = 100)

Variable	Category	n (%)
Sex	Male	46 (46%)
	Female	54 (54%)
Child's age	Under 6 months	8 (8%)
	6–23 months	63 (63%)
	2 years and above	29 (29%)
Residence	Rural	62 (62%)
	Urban	38 (100%)
Exclusive breastfeeding	No	25 (25%)
	Yes	75 (75%)
Immunisation status	Unimmunised	4 (4%)
	Incompletely immunised	44 (44%)
	Fully immunised	19 (19%)
	Unknown	33 (33%)
Diarrhoea	No	63 (63%)
	Yes	37 (100%)
Pneumonia	No	61 (61%)
	Yes	39 (100%)
Type of SAM	Marasmus	65 (65%)
	Kwashiorkor	19 (19%)
	Marasmic kwashiorkor	16 (16%)
Antibiotics	Given	43 (43%)
	Not given	57 (100%)
Folic acid	Given	53 (53%)
	Not given	47 (100%)
Vitamin A	Given	87 (87%)
	Not given	13 (100%)

Among the clinical and feeding characteristics recorded, diarrhoea was present in 37%, fever in 54% and oedema in 9%. Complementary feeding had been

introduced before six months of age in 26 children and after six months in 74. Meat was consumed by 33% of children and cow's milk by 46% [Table 2].

Table 2: Clinical and feeding characteristics (n = 100)

Variable	Category	n (%)
Presence of diarrhoea	Yes	37 (37%)
	No	63 (63%)
Presence of fever	Yes	54 (54%)
	No	46 (46%)
Presence of oedema	Yes	9 (9%)
	No	91 (91%)
Exclusive breastfeeding	Yes	75 (75%)
	No	25 (25%)
Introduction of complementary food	Before 6 months	26 (26%)
	After 6 months	74 (74%)
Meat consumption	Yes	33 (33%)
	No	67 (67%)
Milk intake	Yes	46 (46%)
	No	54 (54%)

Children aged more than 24 months had five times higher odds of anaemia than those under 24 months, and the association was statistically significant (odds ratio 5.05, 95% confidence interval 1.91–13.32, $p = 0.001$). Children with marasmus had lower odds of anaemia than those with kwashiorkor (odds ratio 0.36, 95% confidence interval 0.13–1.05), a difference of borderline significance ($p = 0.085$). Children living in rural areas had 1.90 times higher

odds of anaemia than urban children, without reaching significance ($p = 0.15$). Male sex carried 0.78 times the odds of anaemia compared with female sex ($p = 0.55$). No association was found between anaemia and exclusive breastfeeding (odds ratio 1.00, $p = 1.00$), antibiotic administration (odds ratio 0.97, $p = 1.00$), folic acid supplementation (odds ratio 1.09, $p = 0.84$) or vitamin A supplementation (odds ratio 1.59, $p = 0.56$) [Table 3].

Table 3: Univariate logistic regression of factors associated with anaemia (n = 100)

Variable	Category	Anaemia		Crude OR (95% CI)	p value
		Yes	No		
Age group (months)	< 24	28	43	Reference	0.001
	≥24	23	6	5.05 (1.91–13.32)	
Sex	Male	21	25	0.78 (0.35–1.72)	0.55
	Female	28	26	Reference	
Residence	Rural	36	26	1.90 (0.84–4.31)	0.15
	Urban	15	22	Reference	
Exclusive breastfeeding	No	14	11	1.00 (0.44–2.27)	1.00
	Yes	14	61	Reference	
Type of SAM	Marasmus	16	49	0.36 (0.13–1.05)	0.09
	Kwashiorkor	9	10	Reference	
	Marasmic kwashiorkor	1	15	Reference	
Antibiotics	Given	17	26	0.97 (0.43–2.17)	1.00
	Not given	23	34	Reference	
Folic acid	Given	26	27	1.09 (0.50–2.40)	0.84
	Not given	22	25	Reference	
Vitamin A	Given	36	51	1.59 (0.45–5.56)	0.56
	Not given	4	9	Reference	

Anaemia was present in 51 children. Graded by severity, it was mild in 28 (54.9%), moderate in 19 (37.3%) and severe in 4 (7.8%) [Table 4].

Table 4: Severity of anaemia among anaemic children (n = 51)

Severity	Haemoglobin range (g/dL)	Number of cases	Percentage of anaemic children
Mild	10–10.9	28	54.9
Moderate	7–9.9	19	37.3
Severe	< 7	4	7.8

Classified by peripheral smear morphology, microcytic anaemia was the commonest type and was present in 28 children (54.9%), followed by dimorphic anaemia in 16 (31.4%), macrocytic anaemia in 4 (7.8%) and normocytic anaemia in 3 (5.9%). By sex, dimorphic anaemia occurred in 7

male and 9 female children, normocytic in 2 male and 1 female, microcytic in 14 male and 14 female, and macrocytic in 2 male and 2 female. The chi-square test showed no significant association between morphological type and sex ($\chi = 0.20$, $p = 0.98$) [Table 5].

Table 5: Morphological type of anaemia by sex (n = 51)

Type of anaemia	Male	Female	Total (%)	p value
Dimorphic	7	9	16 (31.4)	$\chi = 0.20$ 0.98
Normocytic	2	1	3 (5.9)	
Microcytic	14	14	28 (54.9)	
Macrocytic	2	2	4 (7.8)	

Serum ferritin was 25.17 ± 11.9 ng/mL in male children and 24.23 ± 10.7 ng/mL in female children ($t = 0.42$, $p = 0.68$). Folic acid was 13.44 ± 4.1 ng/mL in males and 13.01 ± 3.8 ng/mL in females ($t = 0.55$,

$p = 0.58$). Vitamin B12 was 196 ± 149.7 pg/mL in males and 194 ± 119.3 pg/mL in females ($t = 0.08$, $p = 0.94$). None of the three parameters differed significantly between the sexes [Table 6, Figure 1].

Table 6: Biochemical parameters by sex

Biochemical parameter	Male (mean $\pm$ SD)	Female (mean $\pm$ SD)	t value	p value
Ferritin (ng/mL)	25.17 ± 11.9	24.23 ± 10.7	0.42	0.68
Folic acid (ng/mL)	13.44 ± 4.1	13.01 ± 3.8	0.55	0.58
Vitamin B12 (pg/mL)	196 ± 149.7	194 ± 119.3	0.08	0.94

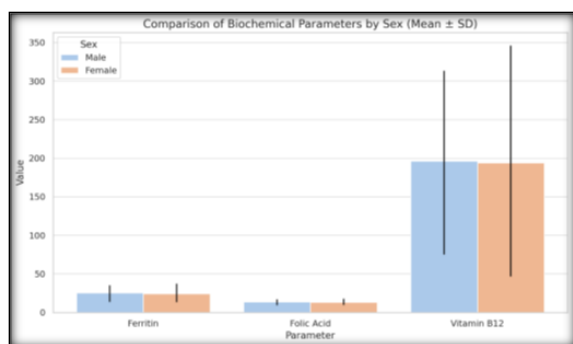


Figure 1: Comparison of biochemical parameters by sex

Haemoglobin was 8.12 ± 2.26 g/dL in male children and 7.27 ± 2.34 g/dL in female children, a significant

difference ($t = 3.389$, $p = 0.001$). Haematocrit was $27.2 \pm 6.78\%$ in males and $21.9 \pm 7.05\%$ in females ($t = 2.96$, $p = 0.004$). Mean corpuscular volume was 86.3 ± 8.74 fL in males and 75.7 ± 12.86 fL in females ($t = 3.905$, $p = 0.0002$). Mean corpuscular haemoglobin concentration was reported as 33.90 ± 2.10 g/dL in both sexes ($t = 4.99$, $p < 0.0001$). Neutrophil percentage was 54.5 ± 6.89 in males and 48.1 ± 8.4 in females ($t = 2.21$, $p = 0.03$).

The remaining parameters did not differ significantly between the sexes: red blood cell count ($p = 0.07$), mean corpuscular haemoglobin ($p = 0.847$), red cell distribution width ($p = 0.67$), total leukocyte count ($p = 0.89$), lymphocyte percentage ($p = 0.42$) and platelet count ($p = 0.48$) [Table 7].

Table 7: Haematological profile by sex

Haematological parameter	Male (mean $\pm$ SD)	Female (mean $\pm$ SD)	t value	p value
Haemoglobin (g/dL)	8.12 ± 2.26	7.27 ± 2.34	3.389	0.001
RBC count (million/mm ³)	3.23 ± 0.92	2.99 ± 1.01	1.832	0.07
Haematocrit (%)	27.2 ± 6.78	21.9 ± 7.05	2.96	0.004
Mean corpuscular volume (fL)	86.3 ± 8.74	75.7 ± 12.86	3.905	0.0002
Mean corpuscular haemoglobin (pg/cell)	26.32 ± 7.87	24.9 ± 6.12	-0.193	0.847
Mean corpuscular haemoglobin concentration (g/dL)	33.90 ± 2.10	33.90 ± 2.10	4.99	< 0.0001
Red cell distribution width (%)	38.87 ± 8.18	36.26 ± 7.75	-0.424	0.67
Total leukocyte count ($\times 10^3$ /mm ³)	12.7 ± 9.1	11.9 ± 9.7	-0.137	0.89
Neutrophil count (%)	54.5 ± 6.89	48.1 ± 8.4	2.21	0.03
Lymphocyte count (%)	52.7 ± 10.4	49.7 ± 9.66	-0.80	0.42
Platelet count ($\times 10^5$ /mm ³)	3.12 ± 2.01	2.87 ± 1.32	-0.70	0.48

DISCUSSION

Anaemia was present in 51 of the 100 children and was mostly mild: 28 (54.9% of anaemic children) mild, 19 (37.3%) moderate and 4 (7.8%) severe, lower than in comparable Indian cohorts. Verma et al., studying 100 children of the same age range in north India, found anaemia in 87% and severe anaemia in 35%.^[10] Thakur et al. reported severe anaemia in 67.3% of 131 children with SAM, a quarter needing transfusion,^[8] and Özkale and Sipahi found anaemia in 97% of 34 children with severe protein-energy malnutrition.^[9] Recruitment here included outpatient and emergency attenders, not inpatients alone, which selects for less complicated disease. Classification also matters: recent haemoglobin fifth centiles are 104.4 g/L at 6–23 months and 110.2 g/L at 24–59 months.¹⁵ Application of a uniform 110 g/L threshold across age groups may have resulted in over-classification of anaemia among younger children and could have influenced the observed association with age.

In our study, microcytic anaemia was observed in 28 cases (54.9%), dimorphic in 16 (31.4%), and macrocytic in only 4 (7.8%). Thakur et al. found microcytic anaemia in 38.6% and megaloblastic anaemia in 30.5%.^[8] Mean vitamin B12 (196 ± 149.7 pg/mL in boys, 194 ± 119.3 pg/mL in girls) and folic acid (13.44 ± 4.1 and 13.01 ± 3.8 ng/mL). Although mean vitamin B12 and folate concentrations did not differ significantly by sex, these group means do not exclude deficiencies in individual children. Verma et al. found vitamin B12 deficiency in 61% and folate

deficiency in 19% of an Indian SAM cohort of identical size and age, B12 deficiency being significantly associated with severe anaemia and low platelet counts.^[10] Özkale and Sipahi, by contrast, found B12 normal in all patients while marrow iron was absent in 58.8%.^[9] Group means can conceal a deficient minority, and dimorphic anaemia in almost a third of these children indicates the possibility of mixed nutritional or other aetiologies.

Age carried the strongest observed association with anaemia; the higher odds among children older than 24 months may relate to differences in dietary patterns, although dietary factors were not directly evaluated as predictors in this analysis. Complementary feeding began after six months in 74 children, meat was eaten by 33% and cow's milk by 46%. National survey data show that only 24.9% of Indian children aged 6–23 months achieve minimum dietary diversity and 12.3% a minimum acceptable diet, the latter being associated with lower odds of anaemia (adjusted odds ratio 0.67).^[17]

Children with marasmus had lower odds of anaemia than those with kwashiorkor (odds ratio 0.36, $p = 0.085$). Greater micronutrient depletion in oedematous malnutrition is possible.^[18,19] Rural residence carried 1.90 times the odds without significance ($p = 0.15$), and no association was found with breastfeeding, antibiotics, folate or vitamin A. The supplements go preferentially to children judged at higher risk, and iron deficiency anaemia in India is driven by diet, infection, inflammation and socioeconomic position, which supplementation alone does not correct.^[20]

Sex differences appeared in the red cell indices but not the biochemical markers. The lower mean corpuscular volume in girls (75.7 ± 12.86 fL versus 86.3 ± 8.74 fL) suggests a more microcytic picture. Morphology showed no association with sex ($\chi = 0.20$, $p = 0.98$) and ferritin was almost identical (24.23 versus 25.17 ng/mL). The difference cannot be attributed to iron status on these data.^[21]

A meta-analysis of 27 studies found that children discharged after admission with severe anaemia had more than twice the six-month mortality of other admissions, and those admitted with SAM over three times the risk.^[22] Anaemia independently predicted in-hospital death in South African children with SAM (odds ratio 3.30),^[23] and Ethiopian children without anaemia were more often cured (adjusted hazard ratio 1.31).^[24] Given the association of anaemia in SAM with adverse outcomes reported in previous studies, timely identification and appropriate management of anaemia remain important in children with SAM.

Limitations: A sample of 100 limited subgroup power, particularly for the 19 children with kwashiorkor and 4 with severe anaemia. C-reactive protein was not measured, which matters because ferritin is an acute-phase reactant and may mislead in an inflamed child; parasitic infection and dietary intake were also unmeasured. No multivariable model was built, so the odds ratios are unadjusted. The study was single-centre, and children were not followed after discharge.

CONCLUSION

Anaemia affected approximately half of children with severe acute malnutrition and was predominantly mild, with microcytic and dimorphic patterns being common, suggesting possible mixed nutritional aetiologies. Age > 24 months was the only factor significantly associated with anaemia, with approximately five-fold higher odds, whereas sex, residence, exclusive breastfeeding, and prior supplementation were not significantly associated. Ferritin, folate, and vitamin B12 concentrations did not differ significantly by sex. Larger multicentre studies with age-appropriate haemoglobin thresholds, assessment of inflammatory status and dietary factors, and multivariable analysis are needed to clarify the determinants of anaemia and establish causal relationships.

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