Research Article

Anemia, Micronutrient Status, and Anthropometric Indicators in Undernourished Under-five Children: A Comprehensive Study on Nutritional Health

Aswanth KS[1], Nikhil Rajvanshi[1], Vinod Kumar[1], Swathi Chacham[1], Prashant Kumar Verma[1*]

[1]*Department of Pediatrics, All India Institute of Medical Sciences (AIIMS), Rishikesh, Uttarakhand, India*

Article Info

[*]***Corresponding Author:***
Prashant Kumar Verma
DM (Medical Genetics), Department of Pediatrics, All India Institute of Medical Sciences (AIIMS)
Rishikesh, Uttarakhand, India
Pin code: 249203
E-mail: 2004pkv@gmail.com
Mobile number: +91-9412592332
ORCID: 0000-0001-8929-5017

Keywords

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Abstract

Introduction: Undernutrition in children is a serious global issue that adversely affects their physical and cognitive development. Anemia is a significant comorbidity contributing to increased mortality in undernourished children. However, it is not being addressed adequately. This study aims to evaluate the clinical and laboratory profile of anemia in undernutrition among under-five children.

Materials and methods: A cross-sectional study was conducted among children between six months to five years of age with undernutrition in a tertiary hospital in North India over a period of one year between December 2021 to December 2022. We observed the prevalence of anemia, its morphological type, micronutrient status, clinical features, and demographic parameters of these children.

Results: Of the 200 children who were enrolled in the study, 72% were found anemic with the proportion of mild, moderate, and severe anemia being 14%,33%, and 25% respectively. The most common type of anemia was microcytic (46.5%) followed by macrocytic (24.3%). Iron (68.7%) was the most common micronutrient deficient in these children with a significant number suffering from vitamin B12 (45.8%) deficiency. Mid-upper arm circumference, worm infestation, pica, and all serum-related parameters had statistical significance in comparison with the severity of anemia.

Conclusion: Despite the significant trend in various aspects of human development, undernutrition and anemia remain a formidable challenge, especially in developing countries. A high proportion of anemia in undernutrition indicates the gravity of the issue, yet not received the deserved attention.

Introduction

Adequate nutrition in early childhood is essential to ensure proper growth, organ development, and function. It is crucial for the effective immune system and neurological development as well. Undernutrition is one of the world's major health concerns, especially in developing countries. It continues to be one of the leading causes of under-five mortality accounting for 68·2% of the total under-5 mortality based on the 1990–2017 trends [1]. WHO defines undernutrition in children below five years in four forms: stunting [Length/height for age (L/HFA) below -2 Z], wasting [weight for height/length (WFH/L) below -2 Z], underweight [weight for age (WFA) below -2 Z], and micronutrient deficiencies. WHO recommends usage of WFH/L Z < -3Z and/or a mid-upper arm circumference (MUAC) value of <115 mm as an anthropometric parameter cut-off for defining children with severe acute malnutrition (SAM) and usage of WFH/L Z -2 Z to -3 Z and/or a MUAC of 115 to 125 mm for the diagnosis of moderate acute malnutrition (MAM) [2]. 149.2 million children were stunted and 45.4 million children were wasted as per 2021 WHO estimation [3]. According to NFHS-5 conducted in 2019-21, among children in India aged less than five years, 35.5% are stunted, 19.3% are wasted 7.7% are severely wasted, and 32.1% have underweight [4]. United Nations (UN) General Assembly on 1 April 2016 proclaimed the years between 2016 to 2025 as "The UN Decade of Action on Nutrition". Hence this decade is an unparalleled opportunity for addressing the issues related to undernutrition [3]. Undernutrition is associated with various comorbidities which have a significant effect on survival as well as long-term quality of life. Anemia is one such comorbidity. According to WHO, around 42% of children less than 5 years of age are anemic. The prevalence of anemia in Indian children aged 6 months to 5 years is 67.1% according to NFHS-5 which has increased from the NFHS-4 survey (58.6%) even after slight improvement in the under-five nutritional status [4]. Micronutrient deficiency remains a major issue in undernourished children. Though Iron is the most common micronutrient deficiency worldwide; vitamin B12 and folate deficiency also contribute to anemia in undernourished children significantly [5].

All management strategies by WHO and national guidelines recommend supplementing and replenishing micronutrients like Vitamin A, Iron, Magnesium, Potassium, etc. However, there is no clear-cut recommendation regarding vitamin B12 assessment and its supplementation in children with malnutrition. There is a lacuna in the literature regarding the anemia status of children with undernutrition. Therefore, this study was planned for estimating the proportion of anemia in children from six months to five years of age with undernutrition and their clinical profile, etiological factors along with micronutrient status with a special focus on iron, vitamin B12, and folic acid.

Materials and Methods

This was a hospital-based observational study done in the Department of Pediatrics of a tertiary care hospital in Northern India over 12 months from December 2021 to December 2022. The study was conducted after obtaining due clearance from the Institutional Ethics Committee (IEC/21/594) and performed in a manner to conform with the Helsinki Declaration of 1975, as revised in 2000 and 2008. As per WHO definitions, children with undernutrition between 6 months to five years of age who presented to outpatient and in-patient department of Pediatrics were enrolled [2]. As per Sarna et al., the prevalence of anemia was 40·5% among 1–4-year-olds [6]. The sample size calculated as per the formula $n=Z2P(1-P)/d2$ and obtained a number of 191. Hence, a convenient sample size of 200 was taken. Children with congenital anomalies, chronic systemic diseases, aplastic anemia, and hematological malignancies were excluded.

Detailed history and clinical examination were done for enrolled children. 1ml blood sample was taken in an EDTA vial and was processed by a five-part automated analyser, Sysmex XN1000 for hemogram. Age-based WHO cut-offs for hemoglobin were used to diagnose anemia. Peripheral smear examination along with serum iron, vitamin B12, and folate levels was done for all children with anemia. A 2 ml blood sample was collected in a plain vacutainer for serum iron, vitamin B12, and folate from which serum was separated. Serum iron was processed by a fully automated analyser, Beckman Coulter AU680. The ADVIA Centaur XP immunoassay system processed serum vitamin B12 and folate levels.

Statictical Analysis

Data collected was recorded in a predesigned data collection form and was stored in Microsoft Excel Sheet. IBM SPSS version 27.0 software was used for data analysis. Descriptive statistics were elaborated as mean/standard deviation or median/inter-quartile range for continuous variables, and frequency with percentage for categorical variables. Data were presented graphically wherever appropriate for data visualization using bar charts/pie charts for categorical data. Appropriate statistical tests were employed where applicable. The p-value of <0.05 was considered statistically significant.

Results

Baseline characteristics

A total of 200 children were enrolled, 117 of whom were males. The mean age of the study population was 2.03 ± 1.24 years. Table 1 represents baseline characteristics. 144 (72%) children had acute malnutrition, with 41.4% SAM and 58.6% MAM.

Table 1: Baseline characteristics of study cohort (N=200).

Parameter		Frequency (%)
Socioeconomic class (Modified Kuppusamy)	Upper	7 (3.5)
	Upper middle	23 (11.5)
	Lower middle	38 (19.0)
	Upper lower	81 (40.5)
	Lower	51 (25.5)
Duration of exclusive breastfeeding (<6 months)		136 (68.0)
Diet (Vegetarian)		104 (52.0)
Maternal education status	Illiterate	4 (2)
	Primary	18 (9)
	Secondary	108 (54)
	Graduate	70 (35)
Immunization status	Adequate	102 (52.0)
	Partial	74 (37.0)
	Unimmunized	24 (12.0)
Weight for age	Normal	20 (10.0)
	-2 to -3 Z	114 (57.0)
	<-3 Z	66 (33.0)
Height/length for age	Normal	51 (25.5)
	-2 to -3 Z	119 (59.5)
	<-3 Z	30 (15.0)
Weight for height/length	Normal	112 (56.0)
	-2 to -3 Z	58 (29.0)
	<-3 Z	30 (15.0)
Mid-upper-arm circumference	>12.5 cm	56 (28.0)
	11.5-12.5 cm	84 (42.0)
	<11.5 cm	60 (30.0)

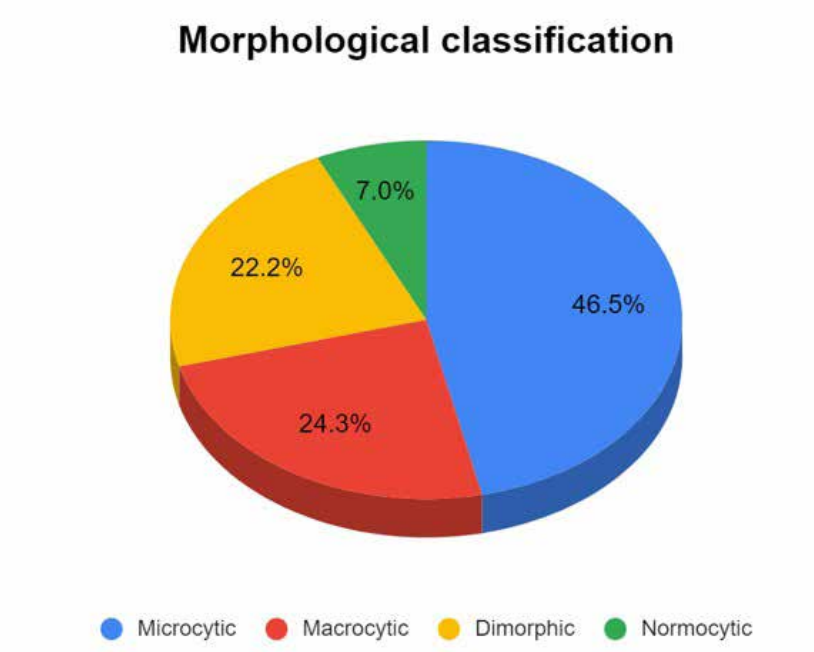
Clinical features

The most common infection in undernourished children was respiratory (15.5%) followed by gastrointestinal (14%) infections. Frequently observed clinical parameters included pica (n=67, 33.5%), pallor (n=58, 29%), worm infestation (n=53, 26.5%), knuckle hyperpigmentation (n=46, 23%), and tremors (n=24,12%).

Anemia

144 (72%) children had anemia in our cohort. Among this, 66 (33%) had moderate anemia, 28 (14%) had mild, and 50 (25%) had severe anemia. The mean hemoglobin was 8.93 ± 2.71 g/dL. The mean values of RBC indices were 25.37 ± 3.56 fL (MCV), 25.37 ± 3.56 pg (MCH), and 28.38 ± 2.66 % (MCHC). The morphological classification of anemia is depicted in Figure 1.

Figure 1: Pie chart depicting the morphological classification of anemia.



The most common micronutrient deficiency in anemic children was iron deficiency (n=99, 68.7%) followed by vitamin B12 (n=66,45.8%), and folic acid (n=15, 10.42%) deficiency. Of this, 33 (22.9%) children had concomitant iron and vitamin B2 deficiencies, 11 (7.6%) had combined folic acid and vitamin B12 deficiency and all three micronutrients were deficient in four (2.7%) children. None of the children had isolated folate deficiency or combined iron and folate deficiencies. The mean serum iron, vitamin B12, and folate values were 69.5 ± 29.48 mcg/dL, 252.6 ± 68.1 pg/mL, and 7.15 ± 3.28 ng/mL, respectively.

A comparison of sociodemographic, anthropometric parameters, and clinical features between anemic and non-anemic children is presented in Table 2. Anthropometric parameters and clinical features were also compared with the severity of anemia (Tables 3 and 4). Serum levels of all three micronutrients i.e., iron, Vitamin B12 and folate were significantly associated with the severity of anemia as represented in Table 5.

Table 2: Comparison of sociodemographic, anthropometric parameters, and clinical features of children with undernutrition with and without anemia (N=200).

Parameter		Anemic (n=144) [n (%)]	Non-anemic (n=56) [n (%)]	p-value*
Male		83 (57.6)	34 (60.7)	0.692
Socioeconomic class	Upper and upper middle	16 (11.1)	15 (26.8)	0.006**
	Lower middle	24 (16.7)	14 (25.0)	
	Upper lower	61 (42.4)	19 (33.9)	
	Lower	43 (29.9)	8 (14.3)	
Duration of exclusive breastfeeding (<6 months)		92 (63.9)	44 (78.6)	0.045**
Maternal education status	Illiterate	3 (2.08)	1 (1.79)	0.02**
	Primary	15 (10.42)	3 (5.36)	
	Secondary	85 (59.03)	23 (41.07)	
	Graduate	41 (28.47)	29 (51.78)	

Weight for age	Normal	13 (9.0)	7 (12.5)	0.722
	-2 to -3 Z	82 (56.9)	32 (57.1)	
	<-3 Z	49 (34.0)	17 (30.4)	
Length/height for age	Normal	34 (23.6)	17 (30.4)	0.616
	-2 to -3 Z	88 (61.1)	31 (55.4)	
	<-3 Z	22 (15.3)	8 (14.3)	
Weight for length/ height	Normal	31 (21.5)	12 (21.4)	0.907
	-2 to -3 Z	66 (45.8)	24 (42.9)	
	<-3 Z	47 (32.6)	20 (35.7)	
Mid-upper-arm circumference	>12.5 cm	26 (18.0)	30 (53.58)	<0.001**
	11.5–12.5 cm	67 (46.5)	17 (30.36)	
	<11.5 cm	51 (35.5)	9 (16.06)	
Worm infestation		53 (36.8)	2 (4.0)	<0.001**
Blood in stool		3 (2.0)	2 (4.0)	0.545
Tremors		16 (11.1)	8 (14.0)	0.535
Pedal edema		13 (9.0)	1 (2.0)	0.071

*Significance levels using the Chi-square test; ** p-value is significant

Table 3: Comparison of anthropometric parameters and severity of anemia (n=144).

Parameters	**Anemia**			**p-value***
	Mild (n=28) [n (%)]	**Moderate (n=66) [n (%)]**	**Severe (n=50) [n (%)]**	
Weight for age				
Normal (n = 13)	2 (15.4)	8 (61.5)	3 (23.1)	0.825
-2 to -3 Z (n = 82)	16 (19.5)	37 (45.1)	29 (35.4)	
<-3 Z (n = 49)	10 (20.4)	21 (42.9)	18 (36.7)	
Length/Height for age				
Normal (n = 34)	10 (29.4)	14 (41.2)	10 (29.4)	0.177
-2 to -3 Z (n = 88)	17 (19.3)	42 (47.7)	29 (33.0)	
<-3 Z (n = 22)	1 (4.5)	10 (45.5)	11 (50.0)	
Weight for height/length				
Normal (n = 74)	9 (12.2)	35 (47.3)	30 (40.5)	0.073
-2 to -3 Z (n = 48)	16 (33.3)	20 (41.7)	12 (25.0)	
<-3 Z (n = 22)	3 (13.6)	11 (50.0)	8 (36.4)	
Mid-upper-arm circumference				
>12.5 cm (n = 26)	10 (38.5)	11 (42.3)	5 (19.2)	0.03**

*Significance levels using the Chi-square test; ** p-value is significant

Table 4: Comparison of clinical features with severity of anemia (n=144).

Clinical features	Anemia			p-value*
	Mild (n=28) [n (%)]	Moderate (n=66) [n (%)]	Severe (n=50) [n (%)]	
Blood in stool/Malena	1 (33.3)	2 (66.7)	0 (0.0)	-
Worm infestation	7 (13.2)	20 (37.8)	26 (49.0)	0.019**
Pica	10 (14.9)	29 (43.3)	28 (41.8)	0.192
Tremors	4 (25.0)	9 (56.3)	3 (18.7)	0.362
Pallor	2 (3.5)	14 (24.1)	42 (72.4)	<0.001**
Pedal edema	5 (38.4)	4 (30.8)	4 (30.8)	0.179
Knuckle hyperpigmentation	12 (26.1)	20 (43.5)	14 (30.4)	0.372
Cheilosis/angular stomatitis	3 (14.3)	8 (38.1)	10 (47.6)	0.399

*Significance levels using the Chi-square test; ** p-value is significant

Table 5: Comparison of laboratory parameters and severity of anemia (n=144).

Parameter	Anemia			p-value*
	Mild (n=28) Mean (95% CI)	Moderate (n=66) Mean (95% CI)	Severe (n=50) Mean (95% CI)	
Iron (mcg/dL)	78.50 (47.0 to 97.0)	48.50 (37.0 to 88.0)	39.50 (23.25 to 67.75)	<0.001**
Vitamin B12 (pg/mL)	265.50 (243.0 to 297.0)	225.00 (175.0 to 264.0)	174.00 (134.0 to 244.0)	<0.001**
Folate (ng/mL)	7.00 (6.62 to 8.0)	6.45 (5.9 to 7.07)	6.30 (5.8 to 7.28)	0.026**

*Significance levels using the Chi-square test; ** p-value is significant

Discussion

According to our study, undernutrition affected males more than females, almost similar to previous studies [7-11]. Studies reported that immunity against infections is better in females than males due to the hormonal impact [12]. Thurstans S et al. in their systematic review stated that boys tend to be more undernourished than girls due to various biological and social mechanisms [13]. Even though undernutrition was expected to be maximum in the lower class, the majority belonged to upper-lower class. A possible explanation is the non-availing of health services by the lower class.

59.5% of children in our study had stunting and 15% had severe stunting. The proportion of wasting and severe wasting was 29% and 15%, respectively. Whereas underweight and severely underweight were 57% and 33%, respectively and 7% had edematous undernutrition. Among 200 enrolled children, 72% had acute malnutrition; out of which, 59% had MAM and 41% had SAM. This was much lower than the observations made by previous studies [10,14,15]. Undernutrition was detected in 11% of children who came for routine immunization. This shows the importance of regular growth monitoring.

The most common infection was found to be respiratory followed by gastrointestinal infections. This was similar in past studies as well [10,16]. However, Kumar R et al. and Garg M et al. reported a higher incidence of gastrointestinal infections than respiratory [14,15]. Hence, we emphasize steps like hygiene practices and immunization to prevent infections of these systems along with early treatment.

Pica and worm infestation were the most common symptoms in the study population. Their proportion was higher than previous studies [16,17]. Tremor as part of infantile tremor syndrome was present in 12% of children which was double the proportion reported by Yaikhomba et al [10]. This difference can be due to the increased number of vegetarian mothers in our study area. Pallor and knuckle hyperpigmentation were two common signs found in anemic children. Thakur et al. reported 33% of children with knuckle hyperpigmentation which was relatively higher than our study [11].

Anemia status

Anemia was found in 72% of undernourished children who participated in the study. Devi et al. reported 69.2% of children with undernutrition as anemic in the under-five population [16]. This was closest to our observation. Most of the other studies found a significantly higher proportion of anemia in under-five children [10,11,14]. The reason can be that most of the other studies were conducted on sick hospitalized children. In contrast, our study contained both in and out-patient children with simple ailments and those who even came for routine immunization. As per WHO classification, 14%

had mild anemia, 33%, and 25% had moderate and severe anemia, respectively. Kumar et al. and Garg M et al. also found moderate anemia more common than mild and severe anemia, similar to our study [13,14]. Whereas, according to certain other studies, undernourished children were found to be more severely anemic [10,11]. Morphologically, microcytic anemia was the most common type (46.5%) followed by macrocytic (24.3%) and dimorphic (22.2%). Thakur et al. also observed microcytic anemia as more prevalent than other types [11].

The proportion of normocytic anemia found in our study was considerably lower than what previous studies noted [10,11,18]. A possible explanation can be the exclusion of chronic diseases in our study which usually present as normocytic anemia.

Similar to our study, Thakur et al. also found iron as the predominant micronutrient deficient [11]. In contrast to this, Yaikhomba T et al. reported a higher proportion of vitamin B12 deficiency than that of iron and folate [10]. Most of the previous studies used serum ferritin to diagnose iron deficiency, which is also an acute inflammatory marker. Whereas in our study, we used serum iron levels. Hence, this can be one probable explanation for our study's increased proportion of iron deficiency. Dimorphic anemia is significantly high in our study population.

Limitations of our study include its single-center design, the inability to assess other iron profile parameters such as total iron-binding capacity and ferritin, and a limited evaluation of micronutrient deficiencies.

Conclusion

The study underscores the persistent challenge of undernutrition and anemia in under-five children, emphasizing its multifaceted clinical and laboratory profile. The study demonstrates a statistical relationship between MUAC, worm infestation, and serum micronutrient levels with anemia severity, providing an integrated perspective on nutritional deficiencies, clinical parameters, and anthropometric indices. This nuanced approach underscores the importance of including routine screening and management of vitamin B12 deficiency in malnutrition protocols, which is not currently a standard recommendation in many guidelines. The findings highlight the importance of comprehensive growth monitoring, micronutrient assessment, and targeted supplementation strategies, particularly in socioeconomically disadvantaged groups. Enhanced focus on early detection and intervention can significantly improve survival and developmental outcomes for this vulnerable population.

Declaration by authors

The manuscript has been read and approved by all the authors, the requirements for authorship, as stated earlier in this document, have been met, and each author believes that the manuscript represents honest work and the information is not provided in another form.

Ethical approval

Approved by Institutional Ethics Committee (IEC/21/594) and performed in a manner to conform with the Helsinki Declaration of 1975, as revised in 2000 and 2008.

Declarations

Funding

Nil.

Conflicts of interest

None declared.

Consent to participate

Signed informed consent obtained from patient.

Consent for publication

Signed informed consent obtained from patient.

References

1. Swaminathan S, Hemalatha R, Pandey A, Kassebaum NJ, Laxmaiah A, Longvah T, et al. The burden of child and maternal malnutrition and trends in its indicators in the states of India: The Global Burden of Disease Study 1990–2017. Lancet Child Adolesc Health. 2019;3(12):855–870 DOI: https://doi.org/10.1016/s2352-4642(19)30273-1
2. WHO child growth standards and the identification of severe acute malnutrition in infants and children [Internet]. [Accessed:20/01/2024]. Available from: www.who.int/childgrowth/standards
3. UNICEF/WHO/World Bank Joint Child Malnutrition Estimates, 2021 Edition. [Internet]. [Accessed:20/01/2024]. Available from: https://data.unicef.org/resources/jme-report-2021
4. National Family Health Survey (NFHS-5), 2019-21 for India [Internet]. [Accessed:20/01/2024]. Available from: https://main.mohfw.gov.in/sites/default/files/NFHS-5_Phase-II_0.pdf
5. WHO fact sheets, February 2025 [Internet]. [Accessed:20/06/2025]. https://www.who.int/news-room/fact-sheets/detail/anaemia
6. Sarna A, Porwal A, Ramesh S, Agrawal PK, Acharya R, Johnston R, et al. Characterisation of the types of anaemia prevalent among children and adolescents aged 1-19 years in India: a population-based study. Lancet Child Adolesc Health. 2020;4(7):515-525. DOI: https://doi.org/10.1016/s2352-4642(20)30094-8
7. Ambadekar NN, Zodpey SP. Risk factors for severe acute malnutrition in under-five children: a case-control study in a rural part of India. Public Health. 2017;142:136–143. DOI: https://doi.org/10.1016/j.puhe.2016.07.018
8. Mishra K, Kumar P, Basu S, Rai K, Aneja S. Risk factors for severe acute malnutrition in children below 5 y of age in India: A case-control study. Indian J Pediatr.

2014;81(8):762–765. DOI: https://doi.org/10.1007/s12098-013-1127-3

9. Murarkar S, Gothankar J, Doke P, Pore P, Lalwani S, Dhumale G, et al. Prevalence and determinants of undernutrition among under-five children residing in urban slums and rural areas, Maharashtra, India: a community-based cross-sectional study. BMC Public Health. 2020;20(1):1559. DOI: https://doi.org/10.1186/s12889-020-09642-0
10. Yaikhomba T, Poswal L, Goyal S. Assessment of iron, folate, and vitamin B12 status in severe acute malnutrition. Indian J Pediatr. 2015;82(6):511-514.DOI: https://doi.org/10.1007/s12098-014-1600-7
11. Thakur N, Chandra J, Pemde H, Singh V. Anemia in severe acute malnutrition. Nutrition. 2014;30(4):440-442.DOI: https://doi.org/10.1016/j.nut.2013.09.011
12. Muenchhoff M, Goulder PJ. Sex differences in pediatric infectious diseases. J Infect Dis. 2014;209 Suppl 3:S120-S126. DOI: https://doi.org/10.1093/infdis/jiu232
13. Thurstans S, Opondo C, Seal A, Wells J, Khara T, Dolan C, Briend A, Myatt M, Garenne M, Sear R, Kerac M. Boys are more likely to be undernourished than girls: a systematic review and meta-analysis of sex differences in undernutrition. BMJ Glob Health. 2020;5(12):e004030 DOI: https://doi.org/10.1136/bmjgh-2020-004030
14. Kumar R, Singh J, Joshi K, Singh HP, Bijesh S. Co-morbidities in hospitalized children with severe acute malnutrition. Indian Pediatr. 2014;51(2):125-127.DOI: https://doi.org/10.1007/s13312-014-0343-x
15. Garg M, Devpura K, Saini S. K, Kumara S. A hospital-based Study on Co-morbidities in children with severe acute malnutrition. J Pediatr Res.2017;4(1):82-88.DOI: https://doi.org/10.17511/ijpr.2017.01.16
16. Devi RU, Krishnamurthy S, Bhat BV, Sahai A. Epidemiological and Clinical Profile of Hospitalized Children with Moderate and Severe Acute Malnutrition in South India. Indian J Pediatr. 2015;82(6):504–510. DOI: https://doi.org/10.1007/s12098-014-1671-5
17. Mani Baskaran V, Naaraayan SA, Priyadharishini D. Comorbidities in children hospitalized with severe acute malnutrition. Indian J Child Health. 2018;5(8):530–532. DOI: https://doi.org/10.32677/IJCH.2018.v05.i08.005
18. Dwivedi D, Singh V, Singh J, Sharma S. Study of anemia in children with severe acute malnutrition. J Nepal Paediatr Soc. 2018;37(3):250–253. DOI: https://doi.org/10.3126/jnps.v37i3.18480