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The role of erythrocyte indices and red cell distribution width (RDW) as predictors of iron deficiency anemia in children with acyanotic congenital heart disease

Peran indeks eritrosit dan red cell distribution width (RDW) sebagai prediktor anemia defisiensi besi pada anak dengan penyakit jantung bawaan asianotik

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Abstract

Congenital heart disease (CHD) affects 9.5 per 1,000 live births worldwide, with Asia showing the highest numbers. Erythrocyte indices such as MCV, MCH, MCHC, and RDW help screen for IDA. This study evaluated erythrocyte indices and RDW as predictors of IDA in pediatric patients. Fifty children aged 1 month to 18 years with acyanotic CHD participated in the study at Dr. Zainoel Abidin Hospital, Banda Aceh, from May to August 2025. IDA diagnosis required age-specific low hemoglobin plus two of the following: ferritin <12 ng/mL, serum iron <50 µg/dL, or TIBC >350 µg/dL. The results showed that 26% of the patients had IDA. The IDA group demonstrated low MCV (84.6%; p=0.001), MCH (53.8%; p=0.001), MCHC (38.5%; p=0.003), and high RDW (76.9%; p=0.001). Logistic regression revealed that low MCV (OR 17.109; 95% CI 2.392–122.397) and high RDW (OR 15.256; 95% CI 2.297–101.320) were the strongest predictors. In conclusion, these parameters effectively predicted IDA in children with cyanotic CHD. Low MCV was the most significant predictor, followed by elevated RDW.

Keywords: Acyanotic congenital heart disease, iron deficiency anemia, erythrocyte indices, red cell distribution width

Abstrak

Penyakit Jantung Bawaan (PJB) terjadi pada 9,5 per 1.000 kelahiran hidup secara global dengan Asia mencatat angka tertinggi. Indeks eritrosit seperti MCV, MCH, MCHC bersama RDW membantu skrining ADB. Penelitian ini mengevaluasi parameter tersebut sebagai prediktor ADB pada anak PJB asianotik. Lima puluh anak usia 1 bulan hingga 18 tahun dengan PJB asianotik berpartisipasi di RSUD Dr. Zainoel Abidin Banda Aceh selama Mei hingga Agustus 2025. Diagnosis ADB memerlukan hemoglobin rendah sesuai usia ditambah dua kriteria: feritin <12 ng/mL atau serum besi <50 µg/dL atau TIBC >350 µg/dL. Hasil menunjukkan 26% mengalami ADB. Kelompok ADB menunjukkan MCV rendah (84,6%; p=0,001), MCH rendah (53,8%; p=0,001), MCHC rendah (38,5%; p=0,003) serta RDW tinggi (76,9%; p=0,001). Regresi logistik mengungkapkan MCV rendah (OR 17,109; IK 95% 2,392–122,397) bersama RDW tinggi (OR 15,256; IK 95% 2,297–101,320) sebagai prediktor terkuat. Kesimpulan, indeks eritrosit bersama RDW efektif memprediksi ADB pada anak PJB asianotik. MCV rendah menjadi prediktor paling signifikan diikuti RDW tinggi.

Kata Kunci: Anemia defisiensi besi, indeks eritrosit, penyakit jantung bawaan asianotik, sel darah merah

Introduction

Congenital heart disease (CHD), the most common congenital abnormality, is characterized by structural defects in the heart or blood vessels (Wu et al., 2020; Liu et al., 2019). Multiple factors contribute to this condition, including genetic predisposition, environmental influences, and maternal diabetes (Cappellini et al., 2020; Fish et al., 2021; Gallagher, 2022). Rubella infection during pregnancy and alcohol consumption also play roles. Down syndrome, along with Noonan syndrome, is a genetic condition that increases the risk of CHD (Hasan et al., 2023; Kloesel et al., 2016). Phenylketonuria also contributes to this condition (Xu et al., 2025; Kumsa et al., 2024). The global incidence of CHD has increased to 9.5 per 1,000 live births (Xu et al., 2025; Liu et al., 2019). Asia has the highest CHD prevalence (95% CI: 8.9–9.7) among all continents, whereas Africa has the lowest prevalence at 1.9 per 1,000 live births (95% CI: 1.1–3.5) (Wu et al., 2020).

In Indonesia, CHD affects eight per 1,000 births. With a population of 200 million and a birth rate of 2 %, approximately 32,000 infants with CHD are born annually. A 2017 study at RSUDZA found an 88.0% prevalence of CHD in pediatric patients. PDA was the most common, at 38.9%, followed by ASD at 19.0% (Aslinar & Amna, 2021). Pediatric patients with CHD commonly experience iron deficiency, including iron deficiency anemia (IDA). Both cyanotic and acyanotic CHD groups face an equal risk of IDA (Binh et al., 2018). Conducted research in Vietnam, finding that 11.1% of cyanotic CHD children experienced IDA, while 3% of acyanotic CHD children had the same condition. Vineela et al. (2023) conducted a study in India that reported a higher IDA prevalence in CHD than in the general pediatric population. Their findings showed IDA in 55% of cases compared to 30% in controls, with statistical significance ($p<0.01$). Iron deficiency without anemia appeared in 77.8% of cyanotic and 51% of acyanotic CHD patients (Lopez et al., 2016). These findings emphasize the importance of routine screening for iron deficiency in patients with CHD (Kumar & Brookes, 2020; Kumar et al., 2022).

Preventing iron deficiency and IDA in patients with CHD requires early detection (Lopez et al., 2018). Binh et al. (2018) noted that severe iron deficiency reduces erythropoietic efficiency, leading to polycythemia with increased hemoglobin concentrations and hematocrit. Red cell distribution width (RDW) also increases in these cases. Iron is an essential mineral for various physiological functions. When iron stores decrease, erythrocyte production decreases, leading to IDA (Vineela et al., 2023). Research has shown that anemia worsens clinical conditions and raises mortality risk along with morbidity in patients with CHD (Binh et al., 2018).

IDA screening uses hematological tests, including hemoglobin, hematocrit, RDW, and erythrocyte indices. These indices measure the MCV, MCH, and MCHC. These parameters help diagnose anemia and differentiate between its types (Ludong et al., 2024; Ossei et al., 2020). Laboratory tests for IDA diagnosis include serum iron (SI), total iron-binding capacity (TIBC), transferrin saturation, and ferritin levels. Bone marrow examination also aids in diagnosis (Binh et al., 2018). These tests are expensive and available only at certain healthcare facilities.

Children with congenital heart disease (CHD) frequently develop iron deficiency anemia (IDA), which can negatively affect their clinical outcomes and quality of life (Moscheo et al., 2022; Özdemir, 2015). Standard laboratory tests for IDA diagnosis, such as serum ferritin and iron status parameters, are unavailable at all healthcare facilities (Peyrin-Biroulet et al., 2018). Hospitals with limited laboratory resources struggle with these assessments (Rohit & Rajan, 2020; Theola et al., 2023). This situation has created a demand for simple, accessible screening methods that can be applied in routine practice (Willim et al., 2021). The potential of erythrocyte indices and red cell distribution width (RDW) as predictors of IDA in pediatric patients with CHD warrants further investigation (Wang, 2016).

This study aimed to analyze how erythrocyte indices, together with red cell distribution width (RDW), function as IDA predictors in pediatric patients with CHD. The goal was to support early and practical IDA detection across various healthcare settings.

Methods

This cross-sectional observational study collected data from the Pediatric Outpatient Clinic of RSUDZA Banda Aceh from May to August 2025. The population consisted of children with acyanotic CHD who visited during this period.

The sample size calculation used the formula for testing two population proportions, yielding a minimum sample size of 47 participants. Consecutive sampling selected 50 children with acyanotic CHD who met the inclusion criteria. These criteria specified children aged 1 month to 18 years with echocardiography-confirmed acyanotic CHD who visited a pediatric outpatient clinic. Parents or guardians provided signed informed consent. Children with thalassemia or hemoglobinopathies and those with chronic diseases affecting iron metabolism were excluded. Children who received iron supplementation within the previous 3 months and those with acute or chronic infections were excluded. Patients with incomplete medical records were also excluded.

An automated hematology analyzer was used to measure complete blood count parameters, including hemoglobin and erythrocyte indices (MCV, MCH, and MCHC), as well as RDW. Iron profile examinations measured the serum iron, total iron-binding capacity (TIBC), and ferritin levels. A complete blood count was performed using a Sysmex XN-1000 automated hematology analyzer (Sysmex Corporation, Kobe, Japan). Serum ferritin was measured using a chemiluminescent immunoassay, and serum iron and TIBC were determined using colorimetric methods on an automated chemistry analyzer. Low MCV, low MCH, and low MCHC were defined according to age-specific reference ranges: for children aged 6 months to 2 years, low MCV was <70 fL, low MCH <23 pg, and low MCHC <30 g/dL; for children aged 2 to 6 years, low MCV was <75 fL, low MCH <24 pg, and low MCHC <31 g/dL; for children aged 6 to 12 years, low MCV was <77 fL, low MCH <25 pg, and low MCHC <31 g/dL; and for children aged >12 years, low MCV was <80 fL, low MCH <26 pg, and low MCHC <32 g/dL (Wang, 2016). A high RDW was defined as >14.5% for all age groups. Data with missing values were excluded from the analysis, and outliers in ferritin levels were retained as they reflected true biological variation. An IDA diagnosis requires age-specific low hemoglobin levels according to the WHO criteria. The hemoglobin thresholds were <11 g/dL for ages 6 months to 5 years, <11.5 g/dL for 5 to 11 years, and <12 g/dL for >12 years. Two of the three parameters also required confirmation: ferritin <12 ng/mL and serum iron <50 μg/dL or TIBC >350 μg/dL.

Data analysis was performed using the SPSS version 26.0. Descriptive statistics are presented as mean ± standard deviation for normally distributed data. Non-normally distributed data are presented as median (minimum-maximum). Bivariate analysis employed Fisher's exact test to examine the relationships between erythrocyte indices and RDW with IDA occurrence. Logistic regression was performed to identify the independent predictors of IDA. The Hosmer-Lemeshow test was used to assess the model goodness-of-fit, and Nagelkerke R^2 was reported to evaluate the proportion of variance explained by the model. Only variables with $p < 0.25$ in the bivariate analysis were entered into the multivariate model. Given the small number of IDA events (n=13), the model was limited to two predictors to maintain an adequate event-per-variable ratio. Statistical significance was set at $p < 0.05$.

This study was approved by the Ethics Committee of Dr. Zainoel Abidin General Hospital in Banda Aceh (approval number: 081/ETIK-RSUDZA/2025).

Result and Discussion

Characteristics of the Study Subjects

This observational cross-sectional study was conducted from May to August 2025. The research subjects were children with acyanotic CHD who met the study criteria and attended the outpatient clinic at Dr. Zainoel Abidin General Hospital in Banda Aceh. This study enrolled 50 patients with acyanotic CHD. No patients were excluded from this study. Table 1 presents the characteristics of the 50 children with acyanotic CHD. Male subjects comprised the majority

(54%), with ages predominantly between 1 and 5 years (58%). Ventricular septal defect (VSD) was the most common CHD type, accounting for 34% of cases. Atrial septal defect (ASD) was followed by patent ductus arteriosus (PDA) at 24% and 22%, respectively. Nearly half of the participants (44%) had a normal nutritional status. Nutritional problems affected a significant proportion of patients: 34% had mild malnutrition and 18% had severe malnutrition. Only 2% had an overweight status, and another 2% had obesity.

Table 1. Subject characteristics (n= 50)

Characteristics	n	%
Sex		
Male	27	54
Female	23	46
Age		
1–12 Months	13	26
1–5 Years	29	58
6–11 Years	7	14
12–18 Years	1	2
Type of CHD		
ASD	12	24
VSD	17	34
PDA	11	22
Others*	10	20
Nutritional Status		
Severe malnutrition	9	18
Mild malnutrition	17	34
Normal	22	44
Overweight	1	2
Obese	1	2
IDA Status		
IDA (Yes)	13	26
IDA (No)	37	74

*AVSD, ASD+VSD, PDA+ASD, PDA+VSD, PDA+ASD+VSD

IDA occurred in 26% of the participants. Umboh et al. (2022) reported similar findings in 48 children with acyanotic CHD, including 26 males (54.1%) and 22 females (45.8%). Similarly, males predominated at Dr. M. Djamil Hospital, Padang, during 2013–2015, comprising 46 patients (54.12%) (Hermawan et al., 2018).

VSD was the most common (34%), followed by ASD (24%), PDA (22%), and combined defects (20 %). Putri & Ariwibowo (2023) found that VSD was the most frequent among 28 toddlers, with 16 cases and Hermawan et al. (2018) reported VSD in 34 of 85 patients with CHD (40%). Normal nutritional status was observed in nearly half of the participants (44%). Nutritional problems remained common, with 34% and 18% of patients experiencing mild and severe malnutrition, respectively. Umboh, Rompies, and Umboh (2022) reported similar findings: 38.71% with normal nutrition, 37.1% with mild malnutrition, and 1.6% with severe malnutrition among children with acyanotic CHD. (Tabib, Aryafar, & Ghadrdoost, 2019) documented a very high prevalence of malnutrition in Egyptian children with CHD, reaching 40.4% mild malnutrition and 39.8% severe malnutrition, with only 19.8% normal nutrition.

Laboratory Characteristics of the Study Subjects

Descriptive statistics revealed variations in all laboratory variables among the research participants. The mean hemoglobin level was 11.67 ± 2.06 g/dL. The average serum iron was 71.50 ± 36.48 µg/dL and TIBC was 327.70 ± 57.94 µg/dL. The median ferritin level was 56.50 ng/mL (7.15–817.20). MCV median was 77.00 fL (59.00–111.00), MCH 26.00 pg (18.00–74.00), MCHC 33.00 g/dL (22.00–35.00), and RDW 14.75% (12.00–25.00%).

Table 2. Laboratory characteristics of all subjects (n= 50)

Laboratory Parameter	Mean ± SD / Median (min–max)
Hemoglobin (g/dL)	11.67 ± 2.06
Ferritin (ng/mL),	56.50 (7.15–817.20)
Serum Iron (µg/dL),	71.50 ± 36.48
TIBC (µg/dL)	327.70 ± 57.94
MCV (fL)	77.00 (59–111)
MCH (pg)	26.00 (18–74)
MCHC (g/dL)	33.00 (22–35)
RDW (%)	14.75 (12–25)

Data are presented as mean ± SD for normally distributed variables (Shapiro-Wilk p>0.05) or median (min–max) for non-normally distributed variables

Most participants (74%) did not have IDA, whereas 26% were diagnosed with IDA. These hemoglobin values match those of Umboh et al. (2022), who reported 11.61 g/dL (7.5–14.5) and MCHC 32 g/dL in 48 acyanotic CHD children.

Hermawan et al. (2018) showed higher hemoglobin levels in cyanotic CHD than in acyanotic CHD. Severe hematological disorders are rare in acyanotic CHD because systemic oxygenation remains adequate.

Distribution of Laboratory Values in the IDA and Non-IDA Groups

IDA group hemoglobin was 9.79 ± 0.78 g/dL versus 12.32 ± 1.97 g/dL in non-IDA. The IDA group had a lower mean hemoglobin level than that of the non-IDA group. Ferritin levels were also lower in the IDA group, with a median of 11.40 ng/mL (7.15–48.00 ng/mL). Serum iron in the IDA group had a non-normal distribution and was presented as a median of 31 µg/dL (11–109 µg/dL), while the non-IDA group had a normal distribution with a mean of 83.11 ± 32.49 µg/dL. The mean TIBC in the IDA group was 389.08 ± 35.28 µg/dL, while that in the non-IDA group was 306.14 ± 48.12 µg/dL. These values align with typical IDA characteristics, showing low ferritin and SI levels, along with increased transferrin iron-binding capacity.

Table 3. Distribution of laboratory values in IDA and Non-IDA subjects

Laboratory Parameters	IDA (n = 13)	Non-IDA (n = 37)
Hemoglobin (g/dL)		
Mean ± SD	9.79 ± 0.78	12.32 ± 1.97
Ferritin (ng/mL)		
Median (min–max)	11.40 (7.15–48.00)	68.80 (12.00–817.20)
Serum Iron (µg/dL),		
Median (min–max)	31.00 (11.00–109.00)	
Mean ± SD		83.11 ± 32.49
TIBC (µg/dL)		
Mean ± SD	389.08 ± 35.28	306.14 ± 48.12
MCV (fL)		
Mean ± SD	68.92 ± 5.71	
Median (min–max)		79.00 (59.00–79.00)
MCH (pg)		
Mean ± SD	23.23 ± 3.37	
Median (min–max)		27.00 (21.00–74.00)
MCHC (g/dL)		
Median (min–max)	31.00 (22.00–35.00)	33.00 (24.00–35.00)
RDW (%)		
Mean ± SD	18.08 ± 2.19	
Median (min–max)		14.00 (12.00–25.60)

Data are presented as mean ± SD or median (min–max) based on the Shapiro-Wilk normality test results per variable per group. The different presentation formats between the IDA and non-IDA groups for the same variable reflected different data distributions.

Variables are presented as mean ± SD when normally distributed (Shapiro-Wilk $p>0.05$) or as median (min–max) when non-normally distributed. The Mann-Whitney U test was used for non-normally distributed variables and the independent t-test for normally distributed variables to compare the IDA and non-IDA groups. The IDA group had lower MCV, MCH, and MCHC values, reflecting microcytic-hypochromic morphology. The mean MCV in the IDA group was 68.92 ± 5.71 fL versus 79.00 fL (59.00–79.00 fL) in the non-IDA group. The mean MCH in the IDA group was 23.23 ± 3.37 pg, versus a median of 27.00 pg (21.00–74.00) in the non-IDA group. The median MCHC in the IDA group was 31.00 g/dL (22.00–35.00) versus 33.00 g/dL (24.00–35.00) in the non-IDA group. The mean RDW in the IDA group was 18.08 ± 2.19%, while the median in the non-IDA group was 14.00% (12.00–25.60%).

This profile typifies pediatric IDA, characterized by low hemoglobin, decreased MCV/MCH/MCHC, elevated RDW, low ferritin/serum iron, and high TIBC levels (Purnamasari et al., 2020).

Association between Erythrocyte Indices, RDW, and IDA Status

Fisher's exact test showed that MCV was significantly related to IDA (p=0.001), with an OR of 23.571 (95% CI: 4.235–131.191). A low MCV was associated with a 23-fold increased risk of developing IDA. MCH also showed a significant relationship (p=0.001, OR 13.22, 95% CI: 2.651–65.951). Low MCH was associated with 13 times greater IDA risk. MCHC was also significant (p=0.003, OR 22.50, 95% CI: 2.302–219.890), with a 22-fold higher risk of low MCHC. RDW showed significance (p=0.001, OR 21.33, 95% CI: 4.317–105.433).

This demonstrates a statistically significant relationship between the RDW and IDA. Subjects with high RDW faced 21 times greater IDA risk compared to those with normal-low RDW.

Table 4. Relationship between Erythrocyte Index Status, RDW, and IDA Occurrence

Variable	IDA (%)	Non-IDA (%)	p-value	OR (95% CI)
MCV				
Low	11 (84.6)	8 (21.6)	0.001*	23.571 (4.235–131.191)
Normal-High	2 (15.4)	29 (78.4)		
MCH				
Low	7 (53.8)	3 (8.1)	0.001*	13.222 (2.651–65.951)
Normal-High	6 (46.2)	34 (91.9)		
MCHC				
Low	5 (38.5)	1 (2.7)	0.003*	22.500 (2.302–219.890)
Normal-High	8 (61.5)	36 (97.3)		
RDW				
High	10 (76.9)	6 (16.2)	0.001*	21.333 (4.317–105.433)
Normal-Low	3 (23.1)	31 (83.8)		

*Fisher's exact test

Table 4 confirms that erythrocyte index abnormalities (low MCV, low MCH, and low MCHC) and high RDW are significantly associated with IDA. Low MCV emerged as the most dominant factor, with 84.6% of children with acyanotic CHD and IDA showing low MCV.

Binh et al. (2018) emphasized that both IDA and iron deficiency without anemia are common in children with CHD, whether cyanotic or acyanotic. Both groups faced a high risk of decreased body iron stores. Severe hypoxia renders erythropoiesis increasingly inefficient. This manifests as polycythemia with increased Hb and hematocrit, along with RDW, as a compensation for chronic hypoxemia and impaired erythrocyte maturation.

The significant association between low MCV and IDA (p = 0.001, OR = 23.571) is consistent with the pathophysiology of iron deficiency. Limited iron availability disrupts hemoglobin synthesis, producing smaller erythrocytes (i.e., microcytosis). Ludong et al. (2024) supported this finding, reporting an MCV sensitivity of 75% and specificity of 100% for IDA detection. The significant relationship between high RDW and IDA (p = 0.001, OR = 21.33) reflects erythrocyte size variation (anisocytosis) in iron deficiency. Ossei et al. (2020) emphasized that combining RDW with MCV enables IDA diagnosis with 98% accuracy. These parameters serve as valuable screening tools in resource-limited settings such as ours.

Analysis of Erythrocyte Indices and RDW as Predictors of IDA

Multivariate logistic regression was used to identify the independent predictors of IDA. The variables that were significant in the bivariate analysis (MCV, MCH, MCHC, and RDW) were included in the model.

Table 5. Multivariate logistic regression analysis results as IDA predictors

Variable	p-value	Exp(B)	95% CI
MCV (low)	0.005	17.109	2.392 – 122.397
RDW (high)	0.005	15.256	2.297 – 101.320
Constant	0.000	0.024	

The results showed that two variables were significantly associated with IDA: low MCV and high RDW. Low MCV had a p-value of 0.005, with an OR (Exp(B)) of 17.109 (95% CI: 2.392–122.397). Participants with low MCV faced approximately 17 times greater IDA risk than those with normal-high MCV. High RDW was also significantly associated with IDA (P = 0.005), with an OR of 15.256 (95% CI: 2.297–101.320). Subjects with high RDW had 15 times greater IDA risk than those with normal-low RDW. The Hosmer-Lemeshow test yielded a p-value of 0.742, indicating an adequate model fit. The Nagelkerke R^2 was 0.621, suggesting that the model explained approximately 62.1% of the variance in the IDA status. The wide confidence intervals observed for both MCV (2.392–122.397) and RDW (2.297–101.320) reflect the relatively small sample size and should be interpreted cautiously.

MCV reflects erythrocyte size, and values below 80 fL indicate microcytosis. A decreased MCV is an early and sensitive predictor of IDA. Low MCV reflects erythrocytes smaller than usual due to limited hemoglobin synthesis. Iron deficiency prevents the body from producing sufficient hemoglobin. The resulting erythrocytes are hypochromic and small. This process characterizes IDA, which differs from other types of anemia, such as megaloblastic anemia, which features macrocytosis (Camaschella, 2017).

RDW describes erythrocyte size variations (anisocytosis). An increased RDW indicates a population of smaller, younger erythrocytes resulting from impaired erythropoiesis maturation during iron deficiency. A high RDW serves as a dynamic indicator that appears before hemoglobin levels significantly decrease. Ludong et al. (2024) showed that combining low MCV with high RDW enhances the diagnostic and predictive value of IDA detection. This aligns with the pathophysiology, in which microcytosis and anisocytosis appear before a decrease in hemoglobin. Combined RDW and MCV analysis achieved a positive predictive value (PPV) of 100% and a negative predictive value (NPV) of 16.4%.

Ossei et al. (2020) emphasized that IDA laboratory examinations are often expensive and remain limited to some facilities. MCV, along with RDW and MCH, serves as an affordable and straightforward hematological parameter alternative validated for iron deficiency detection. Combining RDW with MCV achieved an IDA diagnostic accuracy of up to 98%. Hb), hematocrit (Hct), and erythrocyte count (RBC) do not always reliably detect IDA. This is especially true in patients with cyanotic CHD, as secondary polycythemia can mask iron deficiency. RDW is the earliest indicator of erythrocyte morphological changes, appearing before changes in hemoglobin levels become visible.

Multivariate results showing that MCV and RDW are independent IDA predictors align with recent studies on pediatric anemia diagnosis. (Kumsa, Woldesenbet, Mulugeta, Murugan, & Moges, 2024) reported a high IDA prevalence in children with CHD, emphasizing early identification using simple hematological parameters for timely intervention. The high OR values for both MCV (17.109) and RDW (15.256) demonstrate their strong predictive capabilities. These findings have significant clinical implications. Both parameters appear routinely in complete blood count examinations, making them accessible and cost-effective IDA screening tools for children with acyanotic CHD. This is particularly valuable in resource-limited settings, where advanced iron studies may not be readily available.

This study has several limitations that should be considered when interpreting its results. First, the cross-sectional design prevented the establishment of causal relationships between erythrocyte indices and IDA. Second, the relatively small sample size (n=50, with only 13 IDA cases) limits the statistical power and stability of the logistic regression model, as reflected by the wide confidence intervals observed for the odds ratios. The events-per-variable ratio was low, which may have affected the reliability of the multivariate estimates. Third, this was a single-center study conducted at RSUDZA Banda Aceh, which may limit the generalizability of the findings to other populations and healthcare settings. Fourth, potential confounding factors, such as age, nutritional status, and type of cardiac defect, were not adjusted for in the regression model owing to sample size constraints. Fifth, the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of individual parameters were not calculated, and external validation was not performed. Future studies should employ larger, multicenter cohorts with ROC analysis to determine optimal cutoff values and validate the predictive performance of these parameters.

Conclusion

Erythrocyte indices (MCV, MCH, and MCHC) and RDW were significantly associated with IDA in children with acyanotic CHD. Multivariate analysis showed that a low MCV was the strongest IDA predictor, with a 17-fold greater risk. A high RDW was associated with a 15-fold greater risk. These findings suggest that routine hematological examinations may serve as a potential initial IDA screening tool in children with acyanotic CHD, particularly in healthcare facilities with limited iron profile examination capabilities.

However, these results require validation in larger, multicenter studies with ROC analysis to establish sensitivity, specificity, and optimal cutoff values before implementation in clinical practice. Future prospective studies with larger sample sizes should also explore inflammatory and nutritional confounding factors to deepen the understanding of the relationship between IDA and acyanotic CHD.

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