

Reevaluating Predictors of Extremely Low Birth Weight: The Dominance of Hemoglobin over Maternal Age and the Discovery of 9.25 g/dL as a New Risk Threshold

Ajeng Normala, Hadi Susiarno

Department of Obstetrics and Gynecology Hasan Sadikin Hospital, Faculty of Medicine, Universitas Padjadjaran Jl. Pasteur No.38, Pasteur, Sukajadi District, Bandung City, West Java 40161, Indonesia

Correspondence: Ajeng Normala, Email: Ajengnormala@gmail.com

Abstract

Objectives: Extremely Low Birth Weight (ELBW) is a critical factor influencing neonatal morbidity and mortality. Maternal anemia has been linked to negative pregnancy outcomes; the precise hemoglobin threshold for predicting ELBW risk remains poorly defined, especially in low-resource environments.

Methods: A cross-sectional observational study was carried out at Ciawi District Hospital between 2019 and 2020. Data from medical records on maternal hemoglobin levels (g/dL) and neonatal birth weights (grams) were extracted for analysis. Statistical methods employed included the Kruskal-Wallis and Mann-Whitney tests, as well as ROC curve analysis.

Results: The study comprised 320 cases. The optimal cutoff value for maternal hemoglobin to accurately predict ELBW was identified as 9.25 g/dL (AUC 0.615; $p = 0.045$). Mothers with hemoglobin levels below this threshold exhibited a 2.1-fold increase in the risk of delivering ELBW infants ($p = 0.039$). Additionally, the negative predictive value was determined to be 94.05%, indicating that this threshold may serve as a viable screening tool for assessing the risk of ELBW.

Conclusion: Maternal hemoglobin levels below 9.25 g/dL are significantly correlated with an elevated risk of ELBW. This threshold may function as an effective early screening parameter for identifying high-risk pregnancies, thereby improving maternal and neonatal health outcomes.

Keywords: Birth Weight, ELBW, Hemoglobin, Maternal Anemia, Risk Screening

Evaluasi Ulang Prediktor Berat Badan Lahir Sangat Rendah: Dominasi Hemoglobin pada Usia Ibu dan Penemuan 9,25 g/dL sebagai Ambang Risiko Baru

Abstrak

Tujuan: Berat Badan Lahir Sangat Rendah (BBLR) merupakan faktor penting yang memengaruhi morbiditas dan mortalitas neonatal. Anemia ibu telah dikaitkan dengan hasil kehamilan yang negatif. Ambang hemoglobin yang tepat untuk memprediksi risiko BBLR masih belum didefinisikan dengan baik, terutama di lingkungan dengan sumber daya rendah.

Metode: Metode yang digunakan dalam penelitian ini adalah studi observasional potong lintang dilakukan di Rumah Sakit Daerah Ciawi antara tahun 2019 dan 2020. Dilakukan analisis data dari catatan medis tentang kadar hemoglobin ibu (g/dL) dan berat badan lahir neonatal (gram). Metode statistik yang digunakan meliputi uji Kruskal-Wallis dan Mann-Whitney, dan analisis kurva ROC.

Hasil: Studi ini terdiri atas 320 kasus. Nilai batas optimal hemoglobin ibu untuk memprediksi BBLR secara akurat diidentifikasi sebesar 9,25 g/dL (AUC 0,615; $p = 0,045$). Ibu dengan kadar hemoglobin di bawah ambang batas ini menunjukkan peningkatan risiko melahirkan bayi ELBW sebanyak 2,1 kali lipat ($p = 0,039$). Selain itu, nilai prediktif negatif ditetapkan sebesar 94,05%, yang menunjukkan bahwa ambang batas ini dapat berfungsi sebagai alat skrining yang layak untuk menilai risiko ELBW.

Kesimpulan: Kadar hemoglobin ibu di bawah 9,25 g/dL berkorelasi signifikan dengan peningkatan risiko ELBW. Ambang batas ini dapat berfungsi sebagai parameter skrining dini yang efektif untuk mengidentifikasi kehamilan berisiko tinggi sehingga meningkatkan hasil kesehatan ibu dan bayi baru lahir.

Kata kunci: Anemia Ibu, Berat Lahir, ELBW, Hemoglobin, Skrining Risiko

Introduction

Extremely low birth weight (ELBW) is not merely a clinical issue, but rather a complex representation of unresolved social determinants, reflecting disparities in access to nutrition and quality antenatal care, particularly among low socioeconomic groups. The high prevalence of ELBW signifies not only the burden of neonatal morbidity and mortality, but also a systemic failure to integrate social approaches into maternal and child healthcare services.^{1,2} High levels of maternal anemia, which are linked to poverty, low education rates, poor dietary habits, and inadequate access to comprehensive antenatal screening and interventions (all three dimensions of ELBW) are significant contributors. The prevalence of maternal age as a risk indicator is overstated, but evidence indicates that hemoglobin level, which is less resource-intensive and unbiased, is a more reliable and practical parameter. This is particularly important in this context. Anemia detection and prevention of pregnancy-related complications can be achieved through simple hemoglobin testing as an early screening method.³ In Indonesia, the prevalence of anemia during pregnancy remains high and is correlated with adverse pregnancy outcomes such as low birth weight, prematurity, and intrauterine growth restriction.⁴

ELBW reflects not only a clinical issue but also the complexity of social determinants, such as unequal access to nutrition and antenatal care, particularly among low socioeconomic groups. Maternal anemia, one of the primary contributing factors to ELBW, is influenced by poverty, low educational attainment, inadequate dietary intake, and limited access to screening services. However, there remain significant gaps in its implementation at the community level, largely due to the lack of locally relevant evidence on appropriate hemoglobin cut-off

points for early intervention against ELBW. Therefore, locally grounded research capable of identifying a sensitive and contextually appropriate hemoglobin threshold is urgently needed to strengthen evidence-based screening in primary maternal healthcare services.^{4,5}

The establishment of a standardized hemoglobin cut-off point holds critical urgency within the framework of social obstetrics, particularly to support early warning systems in impoverished or remote areas with limited laboratory infrastructure. Hemoglobin-based anemia screening, which is affordable and easy to perform, enables early detection of ELBW risk at the population level and creates opportunities for more rapid and targeted interventions. By providing empirical data from a local context, such as Ciawi Regional Public Hospital (RSUD Ciawi), this study addresses existing evidence gaps in the field of social obstetrics and offers practical findings to support antenatal care policies that emphasize the prevention of neonatal complications through the detection of severe anemia.^{2,3,5,6,7}

The integration of locally grounded evidence is essential to ensure that implemented interventions are truly relevant to the needs of the target population and capable of addressing social inequalities in maternal and child health. Efforts to combat ELBW and maternal anemia cannot be separated from the broader social context, thus requiring an interdisciplinary approach that combines clinical, social, and public policy dimensions. This study is expected to serve as a foundational step toward the development of screening and intervention strategies, strengthening the role of primary healthcare services in detecting and preventing pregnancy complications that may pose long-term consequences for future generations.^{1,2,4,8}

Method

This study was a quantitative observational research employing a cross-sectional design, conducted at Ciawi Regional General Hospital, Bogor Regency. Data collection was performed retrospectively through a medical record review of mothers and newborns who delivered at the hospital during the period of 2019 to 2020. The study specifically focused on cases involving Low Birth Weight (LBW) infants, including the subcategories of Very Low Birth Weight (VLBW) and Extremely Low Birth Weight (ELBW).

The minimum required sample size for this study was 92 subjects, based on an assumed significance level (α) of 5% and a statistical power of 80% ($\beta = 20\%$). However, to reduce selection bias and enhance analytical power, a total sampling technique was employed, whereby all available data meeting the inclusion criteria during the study period were included in the analysis. A total of 320 records of mothers and newborns were successfully collected and analyzed.

The inclusion criteria for this study were as follows:

- Mothers who gave birth at Ciawi Regional General Hospital during the period of 2019–2020.
- Availability of complete data on maternal hemoglobin levels and infant birth weight.
- Infants born with a birth weight of less than 2.500 grams.
- The exclusion criteria included:
- Mothers with specific chronic diseases known to affect hemoglobin levels (e.g., thalassemia, chronic kidney disease).
- Multiple pregnancies (twins or higher-order multiples).
- Incomplete or illegible medical record data.
- The main variables of this study included:
- Independent variable: Maternal hemoglobin level (g/dL), obtained

from laboratory results during the third trimester and recorded in the medical records.

- Dependent variable: Infant birth weight (grams), documented immediately after delivery based on measurements taken by the medical team.

Data analysis was conducted in several stages. Descriptive analysis was used to present the general characteristics of the respondents, expressed as mean and standard deviation for normally distributed numerical data, or as median and range for non-parametric data, and as proportions for categorical variables. Normality testing was performed using the Kolmogorov–Smirnov and Shapiro–Wilk tests to assess the distribution of the data, with a significance level (α) set at 0.05.

Bivariate analysis employed the Kruskal–Wallis test to compare maternal hemoglobin levels and maternal age across the three low birth weight categories. When further analysis was required, the Mann–Whitney U test was used to compare two groups (ELBW vs. non-ELBW). Subsequently, a Receiver Operating Characteristic (ROC) curve analysis was conducted to evaluate the accuracy of maternal hemoglobin in predicting ELBW cases and to determine the optimal cut-off point based on the balance between sensitivity and specificity.

Likelihood ratio test was applied to assess the diagnostic performance of the identified hemoglobin cut-off in classifying ELBW risk. Diagnostic parameters calculated included sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). A p-value of less than 0.05 was considered statistically significant in all tests.

Result

The baseline characteristics of n=320 study respondents are presented in Table 1.

Participants had a reproductive age range of approximately 15 to 50, with an average maternal age of 29.69 years (SD = 7.26). This result was significant. Maternal hemoglobin levels were low (mean, 9.24 g/dL; SD, 1.36), indicating a high prevalence of maternal anemia in this cohort. The median weight was 2000, while the birth weight had an average of 1842.22 grams (SD = 510.71) and ranged from 100 to 2450grams; these factors are inclusive of infants with ELBW, VLBW, and LBW. Differences in infant birth weight among groups are evaluated in Table 2 for maternal age at delivery. The median age of mothers was 28.5 years for those born to ELBW parents, 27.0 years for those born to VLBW parents, and 29.5 years for those born to normal birth weight (NBW) parents. According to the results of the Kruskal–Wallis test, there is no statistically significant difference in birth weight categories when assessed by maternal age ($p = 0.572$). This suggests that maternal age may not be a reliable predictor of birth weight in this population, according to clinical evidence.

Table 3 presents the differences in maternal hemoglobin levels during delivery among the various birth weight groups. The mean hemoglobin levels in ELBW, VLBW, and LBW infants were 8.9 g/dL, 9.5 ng/dL, or 9.6 gram/day, respectively, among all groups. The difference in median hemoglobin concentration was not statistically significant ($p = 0.129$), but it tended to be lower in mothers of ELBW infants. This pattern suggests that lower maternal hemoglobin levels may have a potential impact on the risk of ELBW; however, the current sample size and variability may not be sufficient to detect equivocal findings. Table 4 presents the ability of maternal hemoglobin categories to predict ELBW. Her mother's risk of delivering ELBW infants was significantly higher with hemoglobin levels below 9.25 (Risk Ratio = 2.118, 95% CI: 1.02–4.374, $p = 0.039$). These metrics exhibited moderate

sensitivity (60.71%) and specificity (59.58%), with a low positive predictive value (1.25%) but high negative predictive value (94.05%).

These findings suggest that although a low maternal hemoglobin level is associated with an increased risk of ELBW, the test is more accurate in ruling out ELBW when hemoalbumin levels are sufficient rather than positive. The data highlights the crucial role of maternal hemoglobin status in fetal growth outcomes, particularly the risk of ELBW. Despite the lack of significant differences in maternal age and hemoglobin levels when analyzed as continuous variables across birth weight groups, selecting a clinically relevant hemoalbumin cut-off (9.25 g/dL) highlights an important risk factor for ELBW. From a clinical perspective, this highlights the importance of screening and managing maternal anemia during pregnancy to minimize the high rates of ELBW, which are linked to increased neonatal morbidity and mortality. The initial step in treating anemia should involve early identification and the appropriate treatment, such as iron supplementation or other interventions. These findings provide public health indications that incorporating maternal hemoglobin monitoring into antenatal care protocols is a practical and cost-effective approach to improve birth rates. The prevention of anemia may be beneficial in reducing the workload on neonatal intensive care units and improving long-term developmental outcomes for infants with low birth weight.

Table 1 Characteristics of Study Respondents

Parameter	N (%)	Mean (SD)	Med (Min – Max)
Maternal Age, Years		29.69 (7.26)	29 (15 – 50)
Hemoglobin		9.24 (1.36)	9.5 (4.4 – 10.9)
Birth Weight, grams		1842.22 (510.71)	2000 (100 – 2450)
Extremely Low Birth Weight	28 (8.8%)		
Very Low Birth Weight	42 (13.1%)		
Low Birth Weight	250 (78.1%)		

Table 2 Differences in Maternal Age at Delivery among Low Birth Weight Infant Groups

Variable	N	Mother’s age, years		p-value
		Med (Min – Max)	Mean Rank	
Extremely Low Birth Weight	28 (8.8%)	28.5 (16 – 44)	165.55	0.572
Very Low Birth Weight	42 (13.1%)	27.0 (16 – 50)	146.65	
Low Birth Weight	250 (78.1%)	29.5 (15 – 45)	162.265	

Table 3 Differences in Maternal Hemoglobin Levels at Delivery among Low Birth Weight Infant Groups

Variable	N	Hemoglobin Level		p-value
		Med (Min – Max)	Mean Rank	
Extremely Low Birth Weight	28 (8.8%)	8.9 (4.4 – 10.9)	126.98	
Very Low Birth Weight	42 (13.1%)	9.5 (5.3 – 10.9)	160.32	0.129
Low Birth Weight	250 (78.1%)	9.6 (4.7 – 10.9)	164.28	

Table 4 Differences and Predictive Ability of Maternal Hemoglobin Categories as a Risk Factor and Predictor of Extremely Low Birth Weight (ELBW)

Test Group	Birth Weight Category				Risk Prevalence (CI 95%)	p-value based LLR	Diagnostic Value	
	ELBW		Non-ELBW					
	N	%	N	%				
Hemoglobin Category	< 9.25 g/dL	17	12.6	118	87.4	2.118 (1.025 – 4.374)	0.039	Sensitivity: 60.71% Specificity: 59.58% Positive Predictive Value (PPV): 12.59% Negative Predictive Value (NPV): 94.05%
	≥ 9.25 g/dL	11	5.9	174	94.1			

Statistical analysis was performed using the likelihood ratio to assess the diagnostic performance of the hemoglobin cut-off in predicting ELBW.

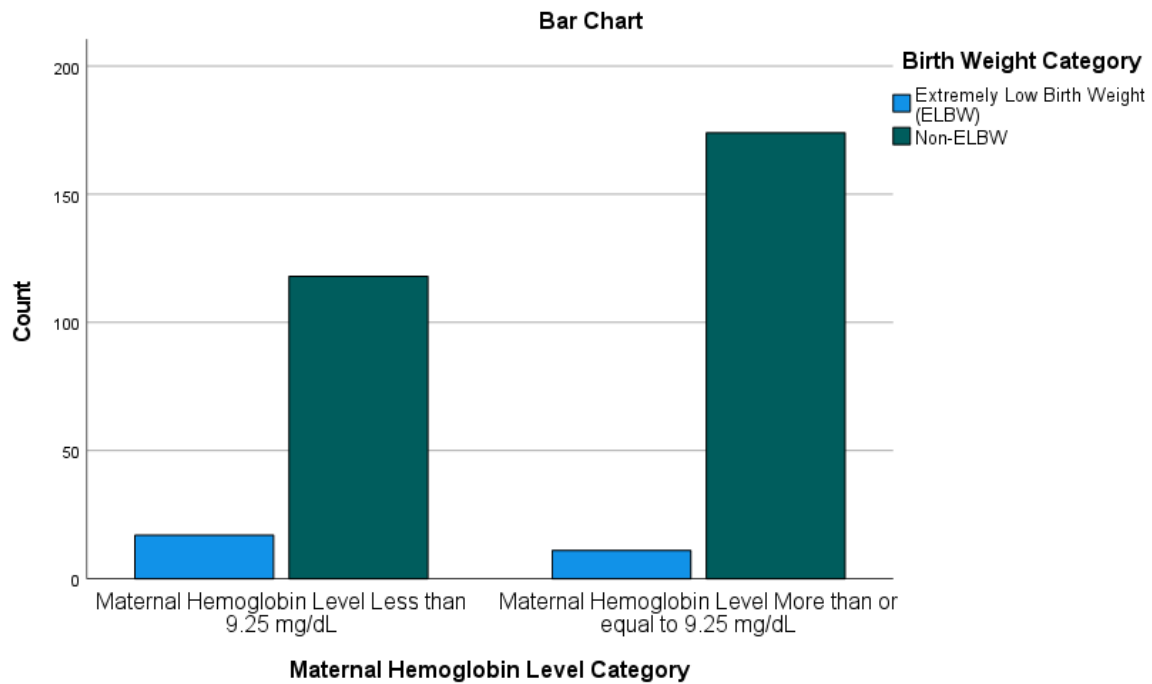


Figure 1 Bar Plot of Maternal Hemoglobin Groups and the Incidence of Extremely Low Birth Weight (ELBW)

Discussion

Recent studies have demonstrated that maternal hemoglobin levels exhibit a stronger and more significant association than maternal age in predicting the risk of ELBW. A large cohort study conducted in Japan found that mothers with hemoglobin levels below 9 g/dL during the first and second trimesters had an increased risk of preterm birth (PTB) and LBW, with statistically significant adjusted odds ratios (aOR), even after multivariate adjustment.⁹ In contrast, maternal age, often used as a risk indicator in antenatal policy, did not demonstrate a significant difference among groups in predicting ELBW incidence. This finding is consistent with other meta-analyses, which have emphasized that biochemical variables such as hemoglobin are more reliable predictors compared to demographic factors like maternal age, whose effects are frequently confounded by other factors such as socioeconomic status and access to healthcare services. Therefore,

hemoglobin emerges as a more relevant and actionable parameter for screening extreme neonatal risk.^{2,9,10,11}

The identification of a hemoglobin cut-off point at 9.25 g/dL as a new risk threshold for ELBW carries important clinical and policy implications. The World Health Organization (WHO) defines anemia in pregnancy as a hemoglobin level below 11 g/dL; however, this threshold is universal in nature and lacks specificity for predicting extreme neonatal outcomes such as ELBW.^{12,13} A cohort study in Japan demonstrated that the risks of PTB and LBW increased markedly at hemoglobin levels below 9 g/dL, whereas the risk within the 9–11 g/dL range was comparatively lower.^{9,12} This finding suggests that a 9.25 g/dL cut-off provides better specificity for predicting ELBW compared to the WHO threshold, thereby reducing the risk of overdiagnosis and unnecessary interventions in mothers with mild to moderate anemia.

The diagnostic accuracy of hemoglobin as a predictor for ELBW at the 9.25 g/dL cut-

off is reflected in the area under the curve (AUC) value of 0.615, which is categorized as weak yet statistically significant. A sensitivity of 60.7% and specificity of 59.6% indicate that hemoglobin at this threshold can identify approximately 60% of ELBW cases, although it is associated with a relatively high false-positive rate. Nevertheless, the negative predictive value (NPV) of 94% provides a strong argument that this cut-off is highly effective for ruling out ELBW risk. In other words, mothers with hemoglobin levels ≥ 9.25 g/dL are highly unlikely to deliver an ELBW infant, allowing healthcare resources to be concentrated on higher-risk groups. A similar approach has been applied in the use of other biomarkers, such as HbA1c in the diagnosis of gestational diabetes, where cut-offs with high NPV are more useful for population-based screening.¹⁴

Maternal hemoglobin levels reflect not only physiological status but also social determinants such as nutritional status, poverty, and access to healthcare services. Epidemiological studies have shown that anemia during pregnancy is strongly correlated with socioeconomic vulnerability, including poverty, low educational attainment, limited access to adequate nutrition and healthcare services.^{8,15,16,17,18} Anemia screening among pregnant women, particularly those from socioeconomically vulnerable groups, is highly relevant within the context of social obstetrics. Community-based interventions aimed at improving nutritional status and access to healthcare services can have a direct impact on reducing the risk of ELBW by improving maternal hemoglobin levels. Hemoglobin functions as an oxygen carrier from the mother to the fetus through the placenta. If hemoglobin levels are low (anemia), the blood's capacity to transport oxygen decreases, resulting in chronic fetal hypoxia. This hypoxia can inhibit fetal growth, increase the risk of LBW, prematurity, and perinatal death. Furthermore, anemia

can also disrupt placental function and increase the risk of complications such as preeclampsia and postpartum hemorrhage. Conversely, excessively high hemoglobin levels often indicate hemoconcentration, which can occur when the mother's plasma volume fails to increase, typically during pregnancy. This hemoconcentration can reduce blood flow to the placenta, thus disrupting the supply of oxygen and nutrients to the fetus. Consequently, the risk of small-for-gestational-age (SGA) birth, LBW, and stillbirth increases. Thus, both maternal anemia and hemoconcentration can impair the transfer of oxygen and nutrients to the fetus through molecular mechanisms directly related to hemoglobin's function as an oxygen carrier.¹⁹

Although the findings of this study are promising, several limitations must be acknowledged. First, the retrospective design and single-center setting limit the generalizability of the results. Second, potential inter-laboratory variation in hemoglobin measurement may affect the accuracy of the proposed cut-off point. Third, the absence of additional data—such as gestational age, nutritional status, and other comorbid factors (e.g., infections, chronic diseases)—may introduce residual bias that influences the interpretation of the association between maternal hemoglobin levels and ELBW.^{2,7,8,9} External validation in diverse populations and across different healthcare settings is essential to ensure the robustness of the 9.25 g/dL cut-off before it can be widely adopted.

Conclusion, the findings of this study indicate that pregnant women with hemoglobin levels below 9.25 g/dL have more than twice the risk of delivering infants with ELBW compared to those with higher hemoglobin levels. This highlights that maternal hemoglobin is not merely a marker of physical health but also reflects the underlying nutritional and social conditions

that significantly influence pregnancy outcomes. Unlike maternal age, traditionally used as a risk indicator, hemoglobin level has demonstrated greater relevance in identifying the risk of severe neonatal complications. This understanding serves as a foundational step toward developing screening and intervention strategies that are more attuned to the social realities of the community, while simultaneously enhancing the capacity of primary healthcare services to detect and prevent pregnancy complications with potential long-term impacts on future generations.

Recommendations

Future research employing prospective study designs is recommended, incorporating additional variables such as gestational age, maternal nutritional status, and socioeconomic background. Moreover, validation across different regions and types of healthcare facilities is essential to ensure that the 9.25 g/dL cut-off can be widely adopted and deliver meaningful benefits for maternal and neonatal health throughout Indonesia.

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