

## Red-cell distribution width and immature to total ratio as predictors of sepsis mortality in preterm neonates

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### Abstract

**Background** Preterm neonates are susceptible to various complications and may require invasive procedures that increase the risk of sepsis, which is the third leading cause of mortality in children. Routine laboratory results, such as red-cell distribution width (RDW) and immature to total neutrophil (I/T) ratio, may be useful as predictors of mortality in neonatal sepsis patients. These laboratory markers have undergone limited testing as mortality predictors in preterm neonates with sepsis.

**Objective** To analyze the predictive ability of RDW and I/T ratio on sepsis mortality in preterm neonates.

**Methods** This prospective cohort study included 42 preterm neonates (gestational age 28-36 weeks + 6 days), with birth weight appropriate to gestational age. The diagnosis of sepsis was established based on the high probable sepsis (HPS) and probable sepsis (PRS) criteria scores. RDW and I/T ratio values were obtained at the time of the sepsis diagnosis. Neonatal mortality was defined as death occurring within the first 28 days of life. Receiver operating characteristic (ROC) curve was used to analyze for associations between mortality and the laboratory markers.

**Results** The median RDW in preterm neonates who died was 16.5% (range 14.0-32.7%). This was relatively similar to the median RDW value in preterm neonates who lived (16.25%; range 14.6-34.3%). ROC curve analysis revealed an area under curve (AUC) of 0.541 (95%CI 0.359 to 0.722;  $P=0.656$ ). The median I/T ratio in preterm neonates who died was 0.13 (range 0.03-0.22), which was similar to the median I/T ratio in preterm neonates who lived (0.15; range 0.11-8.20). The AUC value was 0.387 (95%CI 0.214 to 0.559;  $P=0.213$ ).

**Conclusion** The RDW and I/T ratio values cannot be used as predictors of sepsis mortality in preterm neonates. [Paediatr Indones. 2025;65:462-9; DOI: <https://doi.org/10.14238/pi65.6.2025.462-9>].

**Keywords:** sepsis mortality; preterm neonates; red-cell distribution width; immature to total neutrophil ratio

Preterm neonates are babies born before 37 weeks of gestation. Over the past few decades, the number of premature births has increased worldwide. In Indonesia, in 2010, 15.5% of neonates were born prematurely (around 675,700 neonates) and 6.2% were born with low birth weight in 2018.<sup>1,2</sup>

Preterm neonates have immature immune systems due to born before their immune systems fully developed and mature. They also lack of maternal antibodies such as immunoglobulin (IgG) that should be transferred transplacentally during the third trimester of pregnancy, making them more susceptible to infection. Preterm neonates are also susceptible to complications that require invasive measures such as intravenous access and intubation, which can increase the risk of sepsis.<sup>2</sup>

Neonatal sepsis is a systemic clinical syndrome accompanied by bacteremia, which occur in the first month of life or in those aged <28 days.<sup>3</sup> Sepsis causes

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life-threatening organ dysfunction due to infection-related immune dysregulation.<sup>3</sup> Sepsis can damage to various neonatal organs.<sup>4</sup>

Neonatal sepsis is the third leading cause of death in children in Indonesia, with mortality rate that varies by study, 28.3% at Sanglah Hospital, Denpasar (especially in neonates with low birth weight and prematurity),<sup>5</sup> 22.2% at Dr. M. Haulussy Regional Hospital, Ambon,<sup>6</sup> and 40.74% in Dr. Soetomo General Hospital, Surabaya (related to Apgar score and prematurity).<sup>7</sup> A study at Sanglah General Hospital, Denpasar, in 2017-2018 also reported a mortality rate of 29.8% in babies with low birth weight (LBW).<sup>8</sup> Variation of mortality rates related to neonates sepsis still far from the Sustainable Developmental Goals (SDGs) 3.2 target of 12 deaths per 1,000 live births or 1.2% in 2030.<sup>7</sup>

Neonatal mortality rates related to sepsis need to be reduced, including by identifying markers to predict the final outcome of neonatal sepsis (mortality). Signs of sepsis can be detected in the laboratory using infection biomarkers.<sup>7</sup> The release of inflammatory mediators in sepsis disrupts red blood cells, in terms of hemolysis, production, and/or maturation.<sup>9,10</sup> These events can be assessed by red-cell distribution width (RDW), which has been noted in conditions related to inflammation and infection such as sepsis.<sup>11</sup>

Neutrophils are cellular components of the body's defense mechanism. Young or immature neutrophils can also be released into circulation and can increase absolutely so that it increases the ratio of immature neutrophil cells to total neutrophils, or what is known as the immature to total neutrophil ratio (I/T ratio). I/T ratio is a simple laboratory examination that can be used as an early detection method of neonatal sepsis. An I/T ratio  $>0.2$  indicates that the sepsis process is ongoing.<sup>12</sup>

RDW and I/T ratio values in previous studies have been reported to predict mortality in neonatal sepsis. A study reported the ability of RDW and I/T ratio to predict mortality in term neonates with sepsis, with AUC values of 79.7% ( $P < 0.001$ ) and 68.9% ( $P = 0.01$ ), respectively.<sup>13</sup> Another study also mentioned RDW as an independent predictor of late onset neonates sepsis (LONS) prognosis in preterm neonates, with an AUC value of 76.8%.<sup>14</sup> Goh *et al.*<sup>15</sup> also reported that I/T ratio was an independent predictor of mortality in preterm neonates with LONS.

Severe I/T ratio values  $>0.3$  can predict neonatal sepsis mortality in preterm neonates.<sup>16</sup> It appears that RDW and I/T ratio are predictors of sepsis mortality in preterm neonates, especially in LONS.

The RDW and I/T ratio examinations are fast, easily accessible with complete blood counts, and affordable, especially in developing countries. Therefore, we aimed to evaluate whether RDW and I/T ratio can be effective predictors of mortality in the population of preterm neonates with sepsis treated at Dr. Moewardi Hospital, Surakarta.

## Methods

This study was conducted prospectively to determine the predictive ability of RDW and I/T ratio values on mortality of preterm neonates with sepsis. Neonates that born in gestational age  $<37$  weeks which then classified as extremely preterm ( $<28$  weeks), very preterm (28-31 weeks), moderately preterm (32-33 weeks), and late preterm (34- $<37$  weeks), have birth weight appropriate to its gestational age, neonates with sepsis score in high probable sepsis (HPS) and probable sepsis (PRS) categories were included in study. But preterm neonates with major congenital anomalies of the gastrointestinal tract, hypoxic ischemic encephalopathy, intracranial hemorrhage, necrotizing enterocolitis (NEC), hormonal disorders, or septic shock were excluded. Based on the neonatal mortality rate of 73% related to sepsis from a previous study<sup>14</sup> and an expected sensitivity value of 98%, the required minimum number of subjects was 42. Subjects were selected consecutively.

The study was conducted in the Perinatology Unit (NICU and HCU) of Dr. Moewardi Hospital, Surakarta, from July to December 2024. Sepsis diagnoses were established based on HPS or PRS sepsis scores. HPS criteria are  $\geq 3$  clinical signs related to sepsis (temperature instability, apnea, need for oxygen supplementation, need for ventilation, tachycardia/bradycardia, hypotension, feeding intolerance, abdominal distension, and necrotizing enterocolitis), Hs-CRP  $>5$  mg/mL,  $\geq 2$  changes in serum parameters (CRP, leukocyte, absolute neutrophil and platelet count), and blood culture: positive or negative. PRS criteria are  $<3$  clinical signs related to sepsis, Hs-CRP  $>5$  mg/mL,  $<2$  other serum parameters change, and

negative blood culture.<sup>17</sup>

Mortality of preterm neonates with sepsis was observed from the time of diagnosis to the first 28 days of life. RDW value was the variability of red blood cells (RBCs) in circulation, which is calculated by dividing the standard deviation of RBC volume by the mean corpuscular volume (MCV) multiplied by 100. RBC volume is obtained from a complete blood count (CBC) examination using a hematology analyzer. The I/T ratio value is the comparison of the number of immature neutrophils to the total neutrophils obtained from a peripheral blood smear examination using Giemsa staining. In addition to the RDW and I/T ratio values, characteristics of subjects were collected including age, gender, delivery method, Apgar score, and onset of sepsis.

The results of the study are presented in frequency distribution and percentage for categorical data, and median values and minimum-maximum ranges for continuous data. Testing for differences in proportions was performed using the Chi-square or Fisher's exact test, while differences in median values

according to preterm neonatal mortality status were analyzed using the Mann-Whitney test. The predictive ability of RDW and I/T ratio values on the mortality of preterm neonates with sepsis was analyzed using ROC curves, with SPSS version 22.0 software.

## Results

The study subjects consisted of 42 preterm neonates with gestational age of 28 to <37 weeks and birth weight appropriate for gestational age. The characteristics of subjects are shown in **Table 1**. Preterm neonates with sepsis ranged in age from 0-25 days. The number of males (57.1%) was greater than the number of females (42.9%). Subjects' gestational age was mostly early and moderately preterm (35.7% each). Most neonates (71.4%) were born by Cesarean section and most (64.3%) had low birth weight (LBW). Subjects' median Apgar scores were 5 (range 2-7) at 1 minute, 6 (range 4-8) at 5 minutes, and 7 (range 6-9) at 10 minutes. Most preterm neonates (88.1%) showed early onset of neonatal sepsis (EONS). The

**Table 1.** Characteristics of preterm neonates

Characteristics	Neonatal mortality		Total (n=42)	P value
	Died (n=24)	Lived (n=18)		
Median age (range), days	0 (0-25)	0 (0-25)	0 (0-25)	0.680*
Gender, n(%)				0.857^
Male	14	10	24 (57.1)	
Female	10	8	18 (42.9)	
Gestational age, n(%)				0.238#
Extremely premature	4	0	4 (9.5)	
Early preterm	9	6	15 (35.7)	
Moderately premature	8	7	15 (35.7)	
Late preterm	3	5	8 (19.0)	
Mode of delivery, n(%)				0.200^
Spontaneous	5	7	12 (28.6)	
Caesarean section (CS)	19	11	30 (71.4)	
Birth weight, n(%)				0.013#
Very low birth weight (VLBW)	12	2	14 (33.3)	
Low birth weight (LBW)	12	15	27 (64.3)	
Normal birth weight (NBW)	0	1	1 (2.4)	
Median Apgar score (range)				
1 minute	5 (2-7)	5 (2-7)	5 (2-7)	0.247*
5 minutes	6.5 (4-8)	6 (5-8)	6 (4-8)	0.823*
10 minutes	8 (6-9)	7 (6-9)	7 (6-9)	0.512*
Onset of sepsis, n(%)				1,000^
<72 hours after birth (early)	21 (50.0)	16 (38.1)	37 (88.1)	
>72 hours after birth (late)	3 (7.1)	2 (4.8)	5 (11.9)	

Note: \*Mann Whitney, ^Chi-square, #Fisher exact

mortality rates of preterm neonates with sepsis in this study was 57.1%. Neonatal mortality was significantly associated with birth weight ( $P=0.013$ ), with mortality in very LBW and LBW preterm neonates 57.2% higher than in preterm neonates with normal birth weight (0.0%). Other characteristics of preterm neonates including age, sex, gestational age, mode of delivery, Apgar score, and onset of sepsis were not associated with mortality ( $P>0.05$ ).

The differences in RDW and I/T ratio values according to the mortality status of neonatal sepsis preterm neonates are shown in **Table 2**. The median RDW value in preterm neonates with sepsis who died was 16.15% (range 14.0-32.7). In preterm neonates who lived, the median value was almost the same [16.25% (median 14.6-34.3)]. Mann-Whitney test revealed no significant difference in RDW values between subjects who lived and those who died ( $P=0.656$ ;  $P>0.05$ ). The median I/T ratio of preterm neonates with sepsis was 0.13 (0.03-0.22) in those who died and 0.15 (0.11-8.20) in those who lived. Mann Whitney test revealed that the I/T ratio was not significantly different in those who died or lived

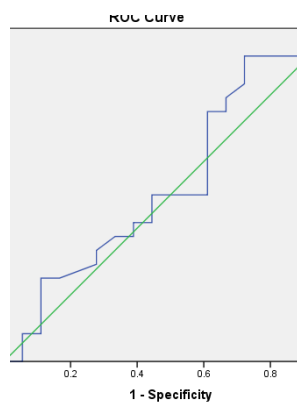
( $P=0.211$ ;  $P>0.05$ ).

The ability of RDW and IT/ratio to predict sepsis mortality in preterm neonates is shown in the ROC curve analyses in **Figures 1 and 2**. **Figure 1** shows that the ROC curve is relatively close to the diagonal line, reflecting a 50% mortality probability level. The AUC value was 54.1% (95%CI 35.9 to 72.2;  $P=0.656$ ), indicating that the RDW value cannot be used to classify/predict mortality in preterm neonates with sepsis.

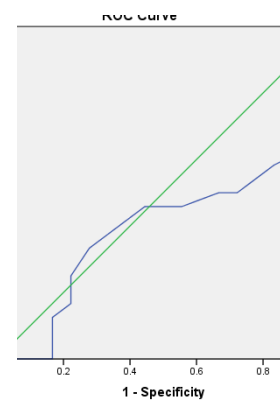
**Figure 2** shows that the ROC curve is below the diagonal line, reflecting a 50% mortality probability level. The AUC value was 38.7% (95%CI 31.4 to 55.9;  $P=0.213$ ), indicating that the I/T ratio also cannot be used to classify mortality in preterm neonates with sepsis. Since both AUC values of RDW and I/T ratio were less than 0.60, the RDW and IT/ratio values failed to predict or classify mortality in preterm neonates with sepsis.

**Table 2.** Analysis of RDW and I/T ratio values based on mortality status of preterm neonates with sepsis

Variables	Mortality		P value
	Died (n=24)	Lived (n=18)	
Median RDW (range), %	16.15 (14.0-32.7)	16.25 (14.6-34.3)	0.656
Median I/T ratio (range)	0.13 (0.03-0.22)	0.15 (0.11-8.20)	0.211



**Figure 1.** ROC curve of RDW and mortality of preterm neonates with sepsis



**Figure 2.** ROC curve of I/T ratio and mortality of preterm neonates with sepsis

## Discussion

The median age of subjects at sepsis diagnosis was 0 (range 0-25) days, in line with the definition of neonatal sepsis as an infection in the bloodstream of neonates aged  $\leq 28$  days. Neonatal sepsis in preterm neonates is due to immune system deficiency, especially from decreased IgG antibodies and opsonization and activation of incompetent complement, as well as the use of instruments to assist delivery.<sup>17</sup> In our study, the majority of preterm neonates (71.4%) underwent Caesarean section (CS). Similarly, a previous study found that 56% of preterm neonates with sepsis underwent CS deliveries.<sup>18</sup> In a study at Fatmawati Hospital, 59.5% of subjects underwent CS.<sup>19</sup>

Subjects were mostly male (57.1%), similar to previous studies that reported male was more frequently seen in sepsis (42-61.9%).<sup>20,21,22</sup> Most neonates had early and moderately preterm gestational age (71.4%). A study similarly noted that the median gestational age of preterm neonates with sepsis was 32 (range 28-36) weeks.<sup>21</sup> Most of our subjects had LBW (64.3%). Likewise, another study reported that the median birth weight of preterm neonates with sepsis was 1,590 (1010-2,320) gr.<sup>21</sup> Haryani *et al.*<sup>19</sup> reported that 69.1% of neonates with LBW experienced neonatal sepsis.

Apgar score is used to assess the presence or absence of asphyxia in neonates immediately after birth. There was no significant difference in Apgar scores between subjects who died and lived. Preterm neonates with sepsis in this study had a median Apgar score of 5 (range 2-7) in the first minute after birth, a median score of 6 (range 4-8) at 5 minutes, and a median score of 7 (range 6-9) at the 10<sup>th</sup> minute. These findings were similar to those in a study at H. Hanafie Muara Bungo Hospital, Jambi, in which the mean 1-minute Apgar score of preterm neonates was 4.8 (SD 1.4), lower than the average 1-minute Apgar score of term neonates [5.7 (SD1.7)]. This difference is due to the fact that preterm neonates have immature organ development.<sup>21</sup> Study at Temanggung Regional Hospital, Temanggung, also reported similar increases in preterm neonates' Apgar scores at measurements 5 and 10 minutes after birth compared to measurements 1 minute after birth. Apgar scores at 1 minute after birth were dominated by mild to moderate asphyxia (41.2%), while at 5

and 10 minutes, most preterm neonates (82.4% and 94.1%, respectively) showed improvements in Apgar scores.<sup>23</sup>

Most of our subjects had EONS (88.1%). Similarly, a study at Fatmawati General Hospital, Jakarta, found that the most common form of neonatal sepsis was EONS (81%).<sup>20</sup> Low birth weight has been associated with mortality in preterm neonates. Similar results were also shown in a study in the NICU of Zeynep Kamil Women and Children's Diseases Training and Research Hospital, Istanbul, Turkey. Neonatal sepsis patients who died had a lower birth weight than those who lived (1,045 g vs. 1,290 g;  $P=0.03$ ).<sup>24</sup> Another study in Serbia also reported that neonates with sepsis who died had significantly lower mean birth weight than those who lived [882.8 (SD 372.2) g vs. 1660.9 (SD 721.1) g;  $P<0,001$ ].<sup>25</sup> Previous studies also stated that the mortality rate of sepsis in very LBW babies was 29.8%,<sup>8</sup> similar to our result of 28.6%. The mortality rate was negatively correlated with birth weight,<sup>24</sup> because neonates with LBW experience deficiencies in the cellular and humoral immune systems and often undergo more invasive procedures.<sup>26</sup>

The mortality rate of our subjects was 57.1%, which was higher than that reported at Sanglah Hospital, Denpasar (35.5%)<sup>13</sup> and Adam Malik Hospital, Medan (42.5%).<sup>27</sup> The difference in mortality rates may have been due to differences in subjects' ages. Our study was on preterm neonates who mostly had LBW and very LBW, while the two previous studies were on term neonates<sup>14</sup> and children aged 2 months to 17 years.<sup>28</sup>

The ROC analysis showed that RDW was not effective in predicting mortality in preterm neonates with sepsis (AUC=0.541; 95%CI 0.359 to 0.722;  $P=0.656$ ). In contrast, a previous study stated that RDW was effective as a predictor of neonatal sepsis mortality in term neonates at Sanglah Hospital, Denpasar (AUC 0.797; 95%CI 0.685 to 0.908;  $P<0.001$ ).<sup>13</sup>

The RDW value in preterm neonates with sepsis, both those who died or still alive, was relatively similar (16.15% vs. 16.25%, respectively). These figures are in the normal range because RDW in almost all preterm neonates in this study was measured  $<72$  hours after birth. A study on 165.613 neonates reported that the lower limit for term and late preterm is 15.5%

to 20% and slightly higher until >23% in preterm. Those ranges persistent till the first two weeks, but in preterm that value could be rise along with erythrocyte transfusions.<sup>29</sup> This could be the one of reason RDW can't predict mortality in preterm neonates with sepsis. Study on sepsis patients treated in the PICU room of Haji Adam Malik Hospital, Medan, also reported that the RDW value was also not associated with pediatric sepsis mortality.<sup>28</sup>

The RDW cannot predict mortality of preterm neonates with sepsis because the age of preterm neonates in our study was 0-25 days and they generally had low and very LBW. Preterm neonates with low/very LBW showed an increase in RDW during the first week of life, and the increase was relatively constant up to one month of life. Thus, RDW in that study cannot be used to predict the development of bronchopulmonary dysplasia because lack of control (preterm neonates with normal birth weight).<sup>30</sup> A condition that becomes one of the most common causes of morbidity and mortality in preterm neonates that have multifactorial etiology both from maternal or neonates, include: lack of antenatal steroids, maternal smoking, preeclampsia, hypoxia, maternal infection, genetic susceptibility, congenital anomalies, lung immaturity, poor nutrition, mechanical ventilation needs, oxygen injury, and sepsis.<sup>31</sup>

Increased RDW in preterm neonates occurs due to vulnerability to the postnatal environment, such as inflammation and sudden cessation of transplacental iron transport, so erythropoiesis becomes ineffective or reticulocytosis occurs.<sup>28</sup> The number of reticulocytes in preterm neonates is usually higher than in term neonates; however, the number can vary greatly depending on the severity of the disease.<sup>32</sup> The increase in the number of reticulocytes in preterm neonates is a rapid physiological response to changes in the intra- to extrauterine environment during the early postnatal period.<sup>33</sup>

While RDW can be elevated in sepsis due to the body's inflammatory response and its impact on red blood cell production and survival, it may not reliably predict mortality in neonates with sepsis. While some studies suggest a correlation between higher RDW and increased mortality risk, others show no significant association or find conflicting results. The predictive value of RDW in neonatal sepsis is still under investigation and may be influenced by various

factors like gestational age, comorbidities, and other biomarkers.<sup>28</sup> The RDW is a relatively non-specific marker, and its levels can be affected by various factors beyond sepsis, such as anemia, vitamin deficiencies, and other inflammatory conditions.<sup>25</sup> Sepsis is a complex condition, and RDW alone may not capture the full picture of disease severity. Other biomarkers like C-reactive protein (CRP), procalcitonin, and white blood cell counts are often used in conjunction with RDW to assess prognosis.<sup>34</sup>

The ROC curve analysis showed that I/T ratio was also not effective in predicting mortality in preterm neonates with sepsis (AUC 0.387; 95%CI 0.214 to 0.559; P=0.213). This finding differed from the study by Sukewanti et al. who found I/T ratio effective as a predictor of neonatal sepsis mortality (AUC 0.689; 95%CI 0.557 to 0.821; P=0.01).<sup>13</sup> The I/T ratio value in a Singaporean study was reported to be an independent predictor of LONS mortality in preterm neonates with very LBW.<sup>15</sup>

The median I/T ratio was 0.13 (range 0.03-0.22) in preterm neonates with sepsis who died and 0.15 (range 0.11-8.20) in those who lived, with no significant difference. The I/T ratio value of both groups was considered normal because it was below 0.2. Since most preterm neonates had EONS, the I/T ratio value WAS not reliable for predicting mortality because increases in I/T ratio can be caused by other physiological conditions. The I/T ratio in EONS can also be misinterpreted in cases of preterm neonates with perinatal asphyxia, maternal hypertension, and long-term oxytocin induction.<sup>15,16</sup> The normal I/T ratio increases to 0.16 during the first 24 hours of birth and decreases to 0.12 in the 5 days after birth until the end of the neonatal period.<sup>16</sup>

Since other factors can affect I/T ratio in preterm neonates with EONS, neutropenia is considered to be a better marker for predicting neonatal sepsis outcomes because conditions such as maternal hypertension, asphyxia, and hemolytic disease can suppress neutrophil counts in neonates.<sup>30</sup> Previous study also stated that I/T ratio is useful for predicting EONS but cannot be relied on as the only predictor of neonatal sepsis outcomes, and is better if combined with CRP measurements.<sup>35</sup> The I/T ratio, while helpful in diagnosing neonatal sepsis, does not consistently predict mortality because other factors beyond the I/T ratio significantly influence mortality

in septic neonates.<sup>36</sup> Sepsis is a dynamic process, and the I/T ratio may change over time, making it challenging to correlate with a single outcome measure like mortality.<sup>37</sup>

The limitations of our study were that we could not fully control for confounding factors that can affect the mortality status of preterm neonates with EONS. These factors, according to previous study, include septic shock, heart failure, respiratory failure, hypothermia, and persistent pulmonary hypertension of the newborn (PPHN).<sup>38</sup> In conclusion, RDW and I/T ratio cannot be used to predict neonatal sepsis mortality in preterm neonates with low and very low birth weight and in those with early onset sepsis.

### Conflict of interest

None declared.

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### References

1. Blencowe H, Lawn JE, Vazquez T, Fielder A, Gilbert C. Preterm-associated visual impairment and estimates of retinopathy of prematurity at regional and global levels for 2010. *Pediatr Res.* 74(SUPPL. 1):35-49. DOI: <https://doi.org/10.1038/pr.2013.205>
2. Badan Penelitian dan Pengembangan Kesehatan, Kementerian Kesehatan Republik Indonesia. Laporan Hasil Riset Kesehatan Dasar (Riskesdas) 2008. Jakarta: Kemenkes RI; 2008.
3. Odabasi IO, Bulbul A. Neonatal Sepsis. *Sisli Etfal Hast Tip Bull.* 2020;54:142-58. DOI: <https://doi.org/10.14744/SEMB.2020.00236>
4. Gestational age and birthweight classification. In: Gomella T, Eyal F, Mohammed F, eds. *Gomella's neonatology management, procedures, on-call problems, disease and drugs.* 8<sup>th</sup> Ed. [cited 2024 November 20]. Available from: <https://accesspediatrics.mhmedical.com/content.aspx?bookid=2762&sectionid=234451055>
5. Kardana IM. Incidence and factors associated with mortality of neonatal sepsis. *Paediatr Indones.* 2011;51:144-8. DOI: <https://doi.org/10.14238/pi51.3.2011.144-8>
6. Thiono MT, Polanunu MR. Profile of neonatal mortality in Dr. M Haulussy Regional Hospital, Indonesia. *CDK.* 2025;52:73-7. DOI: <https://doi.org/10.55175/cdk.v52i2.1247>
7. Harum NA, Utomo MT, Aditiawarman, Gunawan PI. The correlation between apgar score and gestational age with neonatal sepsis associated mortality. *J Widya Med.* 2021;7:141-56.
8. Assa NP, Artana IWD, Kardana IM, Putra PJ, Sukmawati M. The characteristics of neonatal sepsis in low birth weight (LBW) infants at Sanglah General Hospital, Bali, Indonesia. *Intisari Sains Medis.* 2020;11:172-8. DOI: <https://doi.org/10.15562/ism.v11i1.522>
9. Utomo MT, Sumitro KR, Etika R, Widodo ADW. Current-proven neonatal sepsis in Indonesian tertiary neonatal intensive care unit: A hematological and microbiological profile. *Iran J Microbiol.* 2021;13:266-73. DOI: <https://doi.org/10.18502/ijm.v13i3.6386>
10. Ates S, Oksuz H, Dogu B, Bozkus F, Ucmak H, Yanit F. Can mean platelet volume and mean platelet volume/platelet count ratio be used as a diagnostic marker for sepsis and systemic inflammatory response syndrome? *Saudi Med J.* 2015;36:1186-90. DOI: <https://doi.org/10.15537/smj.2015.10.10718>
11. Yunisa D, Ayu PR. Perbedaan Nilai Leukosit, mean platelet volume dan hitung trombosit pada stroke iskemik dengan stroke hemoragik. *J Agromed Unila, J Kes Agromed.* 2017;4:203-10.
12. Celik IH, Hanna M, Canpolat FE, Pammi M. Diagnosis of neonatal sepsis: the past, present and future. *Pediatr Res.* 2022;91:337-50. DOI: <https://doi.org/10.1038/s41390-021-01696-z>
13. Sukewanti NM, Darma Artana IW, Kardana IM, Sukmawati M, Junara Putra P. Red cell distribution width (RDW) sebagai prediktor mortalitas pada sepsis neonatorum. *Medicina (B Aires).* 2019;50:522-6. DOI: <https://doi.org/10.15562/medicina.v50i3.757>
14. Cai N, Chen ZQ, Tao M, Fan WT, Liao W. Mean platelet volume and red blood cell distribution width is associated with prognosis in premature neonates with sepsis. *Open Med.* 2021;16:1175-81. DOI: <https://doi.org/10.1515/med-2021-0323>
15. Goh GL, Lim CSE, Sultana R, De La Puerta R, Rajadurai VS, Yeo KT. Risk factors for mortality from late-onset sepsis among preterm very-low-birthweight infants: A single-center cohort study from Singapore. *Front Pediatr.* 2022;9:1-9. DOI: <https://doi.org/doi:10.3389/fped.2021.801955>

16. Saied DA. Can we rely on the neutrophil left shift for the diagnosis of neonatal sepsis? Need for re-evaluation. *Egypt Pediatr Assoc Gaz.* 2018;66:22-7. DOI: <https://doi.org/10.1016/j.epag.2017.12.002>
17. Gitto E, Karbownik M, Reiter RJ, Xian Tan D, Cuzzocrea S, Chiurazzi P, *et al.* Effects of melatonin treatment in septic newborns. *Ped Res.* 2001;50:756-60. DOI: <https://doi.org/10.1203/00006450-200112000-00021>
18. Singh M, Alsaleem M, Gray CP. Neonatal Sepsis. 2022 Sep 29. In: *StatPearls* [Internet]. Treasure Island (FL): StatPearls Publishing; 2025. PMID: 30285373.
19. Haryani S, Apriyanti YF. Evaluasi terapi obat pada pasien sepsis neonatal. *Farm Klin.* 2022;1:35-44. DOI: <https://doi.org/10.58815/jfklm.v1i1.17>
20. Ningrum ND, Nur A, Suswihardhyono R. Faktor ibu dan bayi yang berpengaruh terhadap kejadian sepsis neonatorum awitan dini pada bayi prematur. *Media Med Muda.* 2015;4:1331-41.
21. Warouw R, Susanah S, Yuniati T. Hubungan antara Red Cell Distribution Width dan Kejadian Sepsis Neonatorum Bayi Prematur. *Sari Pediatr.* 2020;22:104-8. DOI: <https://doi.org/10.14238/sp22.2.2020.104-8>
22. Aro'fah S. Perbedaan nilai apgar score bayi berat lahir rendah cukup bulan dan bayi berat lahir rendah tidak cukup bulan. *Scientia J.* 2019;8:40-7.
23. Sulistyowati E, Ngadiyono. Perbandingan antara nilai apgar pada bayi prematur dengan bayi postmatur di RSUD Temanggung tahun 2013. *J Kebidanan.* 2014;3:8-16. DOI: <https://doi.org/10.31983/jkb.v3i6.110>
24. Gungor L, Arsava EM, Guler A, Togay Isikay C, Aykac O, Batur Caglayan HZ, *et al.*; MASS investigators. Determinants of in-hospital muscle loss in acute ischemic stroke - Results of the Muscle Assessment in Stroke Study (MASS). *Clin Nutr.* 2023;42:431-9. DOI: <https://doi.org/10.1016/j.clnu.2023.01.017>
25. Turhan EE, Gürsoy T, Ovalı F. Factors which affect mortality in neonatal sepsis. *Turk Pediatr Ars.* 2015;50:170-5. DOI: <https://doi.org/10.5152/TurkPediatriArs.2015.2627>
26. Suismaya NLGW, Artana IWD. The characteristics of neonatal sepsis in low birth weight (LBW) infants at Sanglah General Hospital, Bali, Indonesia in 2018. *Intisari Sains Medis.* 2020;11:669-74. DOI: <https://doi.org/10.15562/ism.v11i2.639>
27. Jovičić M, Milosavljević MN, Folić M, Pavlović R, Janković SM. Predictors of Mortality in Early Neonatal Sepsis: A Single-Center Experience. *Medicina.* 2023;59:604. DOI: <https://doi.org/10.3390/medicina59030604>
28. Devina T, Lubis M, Mutiara E, Yanni GN, Saragih RAC, Trisnawati Y, *et al.* Red cell distribution width and mortality in pediatric sepsis. *Paediatr Indones.* 2017;56:320. DOI: <https://doi.org/10.14238/pi56.6.2016.320-4>
29. Christensen RD, Yaish HM, Henry E, Bennett ST. Red blood cell distribution width: reference intervals for neonates. *J Matern Fetal Neonatal Med.* 2015;28:883-8. DOI: <https://doi.org/10.3109/14767058.2014.938044>
30. Oh SH, Do HJ, Park JS, Cho JY, Park CH. Can red cell distribution width in very low birth weight infants predict bronchopulmonary dysplasia? *Medicine.* 2022;101:e28640. DOI: <https://doi.org/10.1097/MD.00000000000028640>
31. Sahni M, Mowes AK. Bronchopulmonary dysplasia. In: *StatPearls* [Internet]. Treasure Island (FL): StatPearls Publishing; 2025. [cited 2025 May 5]. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK539879/>
32. Manito N, Cerqueiro JM, Comín-Colet J, García-Pinilla JM, González-Franco A, Grau-Amorós J, *et al.* Consensus document of the Spanish Society of Cardiology and the Spanish Society of Internal Medicine on the diagnosis and treatment of iron deficiency in heart failure. *Rev Clínica Española (English Ed.).* 2017;217:35-45. DOI: <https://doi.org/10.1016/j.rceng.2016.10.003>
33. Yamada M, Chishiki M, Kanai Y, Goto A, Imamura T. Neonatal reticulocyte count during the early postnatal period. *Pediatr Neonatol.* 2020;61:490-7. DOI: <https://doi.org/10.1016/j.pedneo.2020.04.004>
34. Ratridewi I, Winaputri SL, Sulistijono E, Corebima BIR V, Yunus A. Combination of red cell distribution width and procalcitonin as diagnostic biomarkers of neonatal sepsis in preterm infants. *Paediatr Indones.* 2025;63(1sup):29-34. DOI: <https://doi.org/10.14238/pi63.1sup.2023.29-34>
35. Saboohi E, Saeed F, Khan RN, Khan MA. Immature to total neutrophil ratio as an early indicator of early neonatal sepsis. *Pakistan J Med Sci.* 2019;35:241-6. DOI: <https://doi.org/10.12669/pjms.35.1.99>
36. Pratiwi DIN, Nurikhwan PE, Firdaus MN. CD64 and I/T Ratio as a diagnostic test on neonatal sepsis in Banjarmasin. *Indones J Clin Pathol Med Lab.* 2024;30:168-71. DOI: <https://doi.org/10.24293/ijcpml.v30i2.2077>
37. Haque K. Neonatal sepsis in the very low birth weight preterm infants: Part 1: Review of Patho-physiology. *J Med Sci.* 2010;3:1-10.
38. Goosen LH. Hematology and hemostasis in the pediatric, geriatric, and pregnant populations. In: Keohane EM, Otto CN, Walenga JM, eds. *Rodak's Hematology, Clinical Principles and Applications.* 6<sup>th</sup> ed. Philadelphia: Saunders Elsevier; 2020. p. 813-31.