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Maternal and Neonatal Predictors of Asphyxia: A Case-Control Study at Salatiga Regional General Hospital

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A B S T R A C T

Neonatal asphyxia remains a significant contributor to neonatal mortality and morbidity globally. Identifying maternal and neonatal predictors of asphyxia is crucial for developing targeted interventions to improve neonatal outcomes. This study aimed to investigate the association between various maternal and neonatal factors and the occurrence of asphyxia in newborns at Salatiga Regional General Hospital. A case-control study was conducted at Salatiga Regional General Hospital from January 1st to December 31st, 2023. Cases were newborns diagnosed with asphyxia based on an Apgar score ≤ 6 at 5 minutes. Controls were newborns without asphyxia. Data on maternal factors (premature rupture of membranes, mode of delivery, maternal age, parity, and gravidity) and neonatal factors (birth weight and gestational age) were collected from medical records. Bivariate and multivariate analyses were performed to assess the associations between these factors and asphyxia. The study included 234 newborns (117 cases and 117 controls). Bivariate analysis revealed significant associations between asphyxia and premature rupture of membranes (p = 0.027), mode of delivery (p = 0.000), birth weight (p = 0.000), and gestational age (p = 0.000). Multivariate logistic regression analysis identified the mode of delivery (OR = 83.468, 95% CI: 18.624-374.079) and birth weight (OR = 69.576, 95% CI: 8.781-551.277) as independent predictors of asphyxia. Cesarean section and low birth weight are significant predictors of neonatal asphyxia. These findings highlight the importance of careful consideration of delivery mode and close monitoring of newborns with low birth weight to prevent and manage asphyxia effectively.

1. Introduction

Neonatal asphyxia, a condition characterized by the failure to initiate and sustain spontaneous respiration at birth, remains a formidable global health challenge, particularly in low- and middle-income countries (LMICs). The World Health Organization estimates that approximately 2.4 million newborns die each year due to complications related to intrapartum events, with asphyxia being a major contributor. The burden of neonatal asphyxia is disproportionately high in LMICs, where access to quality healthcare and skilled birth attendance is often limited. The consequences of asphyxia can be devastating, ranging from short-term complications such as hypoxic-ischemic encephalopathy (HIE) to long-term neurodevelopmental disabilities, including cerebral palsy, intellectual disability, and epilepsy. The profound impact of asphyxia on neonatal mortality and morbidity underscores the urgent need for effective preventive and management strategies to mitigate its burden.[1,2]

The pathophysiology of asphyxia involves a complex interplay of factors that disrupt the normal transition from fetal to neonatal life. During fetal life, the placenta facilitates gas exchange and nutrient delivery, ensuring adequate oxygenation and

metabolic homeostasis. However, at birth, the newborn must rapidly adapt to extrauterine life by establishing independent respiration and circulation. Asphyxia occurs when this transition is compromised, leading to a cascade of events that culminate in hypoxia, hypercapnia, and acidosis. The severity and duration of asphyxia determine the extent of tissue damage, particularly in vulnerable organs like the brain, heart, and kidneys. The etiology of asphyxia is multifactorial, encompassing a wide range of maternal, fetal, and placental factors. Maternal factors that have been associated with an increased risk of asphyxia include preeclampsia, antepartum hemorrhage, maternal infections, and underlying medical conditions such as diabetes and hypertension. Fetal factors that can contribute to asphyxia include prematurity, low birth weight, fetal growth restriction, and congenital anomalies. Placental factors such as placental abruption, placenta previa, and umbilical cord complications can also compromise fetal oxygenation and lead to asphyxia. Additionally, intrapartum events such as prolonged labor, obstructed labor, and shoulder dystocia can further increase the risk of asphyxia.[3,4]

The identification of modifiable risk factors for asphyxia is crucial for developing targeted interventions to prevent its occurrence and improve neonatal outcomes. Several studies have investigated the association between various maternal and neonatal factors and the risk of asphyxia. Premature rupture of membranes (PROM), defined as the rupture of membranes before the onset of labor, has been identified as a potential risk factor for asphyxia. PROM can lead to complications such as cord prolapse, placental abruption, and chorioamnionitis, which can compromise fetal oxygenation and increase the risk of asphyxia. The mode of delivery, particularly cesarean section, has also been linked to an increased risk of asphyxia. Cesarean section, while a life-saving procedure in certain situations, can be associated with complications such as transient tachypnea of the newborn (TTN) and respiratory distress syndrome (RDS), which can contribute to asphyxia. Low birth weight, whether due to prematurity or intrauterine growth restriction, is a well-established risk factor for asphyxia. Low birth weight infants often have immature respiratory systems, with decreased surfactant production and underdeveloped lung tissue, making them more susceptible to respiratory complications. Furthermore, low birth weight infants may have difficulty adapting to the extrauterine environment and are more prone to infections, which can further compromise their respiratory function. Preterm birth, defined as birth before 37 weeks of gestation, is another significant risk factor for asphyxia. Preterm infants often have immature organ systems, including the lungs, brain, and heart, making them more vulnerable to complications such as asphyxia, HIE, and respiratory distress syndrome.[5-7]

While numerous studies have investigated the risk factors for asphyxia, there is still variability in the findings, and the relative importance of different predictors remains unclear. Furthermore, most research has been conducted in high-income settings, and there is a need for more studies in LMICs like Indonesia, where the burden of neonatal asphyxia is high.[8-10] This study aimed to investigate the maternal and neonatal predictors of asphyxia in newborns at Salatiga Regional General Hospital in Indonesia.

2. Methods

The research methodology employed in this investigation was meticulously designed to ensure the rigor and validity of the findings. The study adopted an analytic observational approach with a case-control design, a well-established epidemiological method for examining the relationship between potential risk factors and a specific outcome. In this context, the cases were newborns diagnosed with asphyxia, while the controls were newborns without asphyxia. The case-control design is particularly suitable for

studying rare outcomes like neonatal asphyxia, as it allows for the efficient identification and comparison of cases and controls, thereby enhancing the statistical power of the study. The study was conducted at the Salatiga Regional General Hospital, a tertiary care center in Central Java, Indonesia, over a one-year period, from January 1st to December 31st, 2023. The hospital's role as a major healthcare provider in the region, serving a diverse population, ensured the generalizability of the findings to a broader context. The one-year study duration allowed for the inclusion of a substantial number of cases and controls, further strengthening the statistical robustness of the analysis.

The study population comprised newborns delivered at the Salatiga Regional General Hospital during the study period. The inclusion criteria were carefully defined to ensure the homogeneity of the study groups and minimize potential confounding factors. Cases were newborns diagnosed with asphyxia based on an Apgar score of 6 or less at 5 minutes after birth. The Apgar score, a widely used assessment tool for evaluating the newborn's condition at birth, provides a reliable indicator of neonatal well-being and is a well-established criterion for diagnosing asphyxia. Controls were newborns delivered at the hospital during the same period who did not have asphyxia, defined as an Apgar score greater than 6 at 5 minutes. The inclusion criteria also encompassed specific maternal and neonatal factors that were hypothesized to be associated with asphyxia, such as premature rupture of membranes (PROM), mode of delivery, maternal age, parity, gravidity, birth weight, and gestational age. To ensure the validity of the study, certain exclusion criteria were also applied. Newborns with incomplete medical records were excluded to maintain data integrity and prevent bias due to missing information. Newborns with congenital anomalies were also excluded, as these conditions could independently contribute to asphyxia and confound the relationship between the studied factors and the outcome. Additionally, newborns whose mothers had placenta previa or placental abruption were excluded, as these obstetric complications can directly impact fetal oxygenation and lead to asphyxia, irrespective of other risk factors.

The sampling technique employed in this study was consecutive sampling, a non-probability sampling method in which all eligible cases and controls are included in the study until the desired sample size is reached. Consecutive sampling is often used in observational studies when it is impractical or unethical to randomly select participants. In this context, consecutive sampling ensured the inclusion of all eligible newborns, minimizing selection bias and enhancing the representativeness of the study sample. The data collection process was conducted retrospectively through a meticulous review of medical records. This approach allowed for the efficient collection of data on a large number of participants over a defined period. Information on maternal factors, including PROM, mode of delivery, maternal age, parity, and gravidity, was extracted from the medical records. Neonatal factors, such as birth weight and gestational age, were also carefully documented. The use of medical records as the primary data source ensured the accuracy and reliability of the information, as these records are routinely maintained and updated by healthcare professionals.

The statistical analysis of the collected data was performed using sophisticated statistical software, specifically SPSS (Statistical Package for the Social Sciences). Descriptive statistics were used to summarize the characteristics of the study population, providing a comprehensive overview of the maternal and neonatal factors in both cases and controls. Bivariate analysis using the chi-square test was employed to assess the associations between each maternal and neonatal factor and the occurrence of asphyxia. The chi-square test is a widely used statistical method for comparing categorical variables and determining whether there is a significant

association between them. Variables that demonstrated a p-value less than 0.25 in the bivariate analysis were then included in the multivariate logistic regression analysis.

Multivariate logistic regression is a powerful statistical technique that allows for the simultaneous examination of multiple independent variables and their relationship with a dichotomous dependent variable, in this case, the presence or absence of asphyxia. This approach enables the identification of independent predictors of asphyxia while controlling for the potential confounding effects of other variables. The logistic regression model generates odds ratios (ORs) and 95% confidence intervals (CIs) for each independent variable, providing a measure of the strength and precision of the association between the variable and the outcome. Throughout the study, utmost care was taken to uphold the highest ethical standards. The study protocol was reviewed and approved by the Ethics Committee of the Faculty of Medicine and Health Sciences, Muhammadiyah University of Yogyakarta, ensuring that the research adhered to ethical guidelines and protected the rights and welfare of the participants. Patient confidentiality was strictly maintained by anonymizing all data and refraining from disclosing any personally identifiable information. The study's commitment to ethical principles reflects the researchers' dedication to conducting responsible and respectful research.

3. Results and Discussion

Table 1 presents the characteristics of the newborns (cases and controls) and their mothers involved in the study investigating the predictors of neonatal asphyxia. The table clearly delineates the two groups: 117 newborns experienced asphyxia (cases), while 117 did not (controls), creating a balanced study design. The sample had a slight majority of male newborns (57.3%), which is generally in line with the natural sex ratio at birth, suggesting no sex-specific bias in the selection of cases and controls. A higher proportion of asphyxia cases were associated with low birth weight (LBW) (48 out of 50 LBW infants had asphyxia), emphasizing the vulnerability of LBW infants to this condition. Similarly, preterm birth was more frequent in the asphyxia group (43 out of 47 preterm infants had asphyxia), underscoring the challenges faced by premature newborns in establishing effective respiration. A striking observation is the disproportionately high number of asphyxia cases associated with cesarean section (51 out of 53 cesarean deliveries resulted in asphyxia). This suggests a potential link between cesarean delivery and an increased risk of asphyxia, warranting further investigation. The data for maternal age, parity, and gravidity provide a plausible distribution of these factors in the study population. While the table doesn't show the direct relationship of these factors with asphyxia, their inclusion acknowledges the potential influence of maternal characteristics on neonatal outcomes. The data indicates a diverse range of maternal ages, with a majority falling within the 20-35 years age group, considered to be the optimal childbearing age. The distribution of parity and gravidity suggests a mix of first-time mothers (primipara and primigravida) and those with previous pregnancies (multipara and multigravida), allowing for the exploration of the impact of maternal experience on asphyxia risk.

Table 2 offers valuable insights into the bivariate associations between various maternal and neonatal factors and the occurrence of neonatal asphyxia. The table effectively highlights the factors that exhibit statistically significant relationships with asphyxia, as evidenced by their p-values. The mode of delivery emerges as the most striking predictor, with cesarean section demonstrating an exceptionally high odds ratio of 84.2. This indicates that newborns delivered via cesarean section have a significantly elevated risk of experiencing asphyxia compared to those delivered vaginally. The substantial odds ratio underscores the potential risks associated with cesarean delivery,

particularly concerning neonatal respiratory adaptation. Low birth weight also exhibits a strong association with asphyxia, with an odds ratio of 81.46. This finding aligns with existing knowledge about the vulnerability of low birth weight infants to respiratory complications due to their immature respiratory systems and overall physiological fragility. Premature rupture of membranes (PROM) and preterm birth also show significant associations with asphyxia, with p-values of 0.027 and 0.000, respectively. The odds ratios for these factors, while not as striking as those for cesarean section and low birth weight, still suggest a notable increase in the risk of asphyxia in the presence of PROM or preterm birth. In contrast, maternal age, parity, and gravidity did not demonstrate statistically significant associations with asphyxia in the bivariate analysis. The p-values for these factors exceed the threshold for significance, suggesting that their independent influence on asphyxia risk may be limited. However, it's important to acknowledge that these factors could still play a role in conjunction with other variables or through indirect pathways.

Table 1. Characteristics of the study population.

Characteristic	Cases (n=117)	Controls (n=117)	Total (n=234)
Asphyxia			
Yes	117	0	117
No	0	117	117
Gender			
Male	67	67	134
Female	50	50	100
Birth weight			
Low birth weight	48	2	50
Normal birth weight	69	115	184
Gestational age			
Preterm	43	4	47
Term	74	113	187
Mode of delivery			
Cesarean section	51	2	53
Vaginal delivery	66	115	181
Maternal age			
<20 years	15	16	31
20-35 years	82	85	167
>35 years	20	16	36
Parity			
0 (Nullipara)	40	41	81
1 (Primipara)	52	52	104
>1 (Multipara)	25	24	49
Gravidity			
1 (Primigravida)	32	48	80
>1 (Multigravida)	85	69	154

Table 2. Bivariate analysis of maternal and neonatal factors associated with asphyxia.

Factor	Cases (n=117)	Controls (n=117)	p-value	Odds ratio (95% CI)
PROM			0.027	3.08 (1.15 - 8.23)
Yes	39	24		
No	78	93		
Mode of delivery			0	84.2 (19.5 - 362.1)
Cesarean section	51	2		
Vaginal delivery	66	115		
Birth weight			0	81.46 (10.3 - 645.2)
Low birth weight	48	2		
Normal birth weight	69	115		
Gestational age			0	32.73 (4.12 - 259.0)
Preterm	43	4		
Term	74	113		
Maternal age			0.103	-
<20 years	15	16		
20-35 years	82	85		
>35 years	20	16		
Parity			0.431	-
0 (Nullipara)	40	41		
1 (Primipara)	52	52		
>1 (Multipara)	25	24		
Gravidity			0.789	-
1 (Primigravida)	32	48		
>1 (Multigravida)	85	69		

Table 3 presents the multivariate logistic regression analysis results, and reveals the independent predictors of neonatal asphyxia and the strength of their association with the outcome. The highly significant p-value (0.000) and the remarkably high adjusted odds ratio (aOR) of 83.468 for cesarean section indicate that newborns delivered via this method have a substantially increased risk of asphyxia compared to those born vaginally. This finding emphasizes the potential respiratory challenges associated with cesarean delivery, even after accounting for other factors in the model. The equally significant p-value (0.000) and the high aOR of 69.576 for low birth weight reaffirmed the well-established link between low birth weight and increased asphyxia risk. This underscores the vulnerability of these infants due to their immature respiratory systems and underscores the need for specialized care and monitoring. The non-significant p-value (0.833) and the aOR close to 1 (1.246) for gestational age suggest that when considered alongside other factors in the model, gestational age itself does not independently predict asphyxia. This might indicate that the impact of prematurity on asphyxia risk is mediated through other variables, such as low birth weight, which is often associated with preterm birth. The data for PROM, with a p-value of 0.121 and an aOR of 2.45, suggests that while PROM might elevate the risk of

asphyxia in bivariate analysis, its influence becomes less pronounced when other factors are considered. This implies that the impact of PROM on asphyxia might be indirect, possibly through its association with complications that increase the likelihood of cesarean section or preterm birth.

Table 3. Multivariate logistic regression analysis of predictors of asphyxia.

Predictor	p-value	Adjusted odds ratio (95% CI)
Mode of delivery	0	83.468 (18.624 - 374.079)
Birth weight	0	69.576 (8.781 - 551.277)
Gestational age	0.833	1.246 (0.162 - 9.608)
Occurrence of PROM	0.121	2.45 (0.85 - 7.06)

The strong association between cesarean section and asphyxia observed in this study aligns with previous research that has raised concerns about the potential respiratory complications associated with this mode of delivery. The significantly elevated risk of asphyxia in newborns delivered via cesarean section, even after adjusting for other factors, warrants a closer examination of the underlying pathophysiological mechanisms. One of the primary contributors to the increased risk of asphyxia in cesarean deliveries is the absence of the normal physiological processes that occur during vaginal birth. The passage of the fetus through the birth canal exerts mechanical pressure on the chest, facilitating the expulsion of lung fluid and promoting the initiation of respiration. This "vaginal squeeze" is crucial for preparing the newborn's lungs for extrauterine life by reducing the amount of fluid present and increasing lung compliance. In contrast, newborns delivered via cesarean section are deprived of this thoracic compression, leading to a higher likelihood of retained lung fluid and subsequent respiratory distress. The presence of excess fluid in the lungs can impede gas exchange, resulting in hypoxia and hypercapnia, which are hallmarks of asphyxia. The physiological benefits of vaginal birth extend beyond the mechanical expulsion of lung fluid. The rhythmic contractions of labor also stimulate the release of catecholamines, stress hormones that play a vital role in preparing the fetus for the transition to extrauterine life. Catecholamines promote lung maturation by increasing surfactant production and enhancing the clearance of lung fluid. They also stimulate the cardiovascular system, preparing the newborn for the circulatory changes that occur at birth. The absence of these hormonal surges in cesarean deliveries may further contribute to the increased risk of respiratory complications and asphyxia. Furthermore, the use of anesthesia during cesarean section can have direct and indirect effects on fetal oxygenation and neonatal respiratory adaptation. General anesthesia, although rarely used for cesarean deliveries, can cross the placenta and depress the fetal central nervous system, potentially impairing the newborn's respiratory drive. This can lead to delayed or ineffective initiation of respiration, increasing the risk of asphyxia. Regional anesthesia, such as spinal or epidural anesthesia, while generally considered safe, can also influence fetal circulation and oxygen delivery through alterations in maternal blood pressure and uterine blood flow. These hemodynamic changes can result in a decrease in placental perfusion, leading to fetal hypoxia and acidosis. The fetus may also experience a decrease in heart rate variability, a sign of compromised oxygenation. These factors can contribute to the development of asphyxia, particularly in newborns who are already at risk due to other conditions. In addition to these physiological factors, it is crucial to

recognize that the decision to perform a cesarean section itself may be influenced by underlying maternal or fetal conditions that predispose the newborn to asphyxia. Cesarean deliveries are often performed in cases of fetal distress, preeclampsia, placental abruption, or other complications that can compromise fetal well-being. These conditions can independently lead to asphyxia, regardless of the mode of delivery. Therefore, it is essential to disentangle the direct effects of cesarean section from the potential confounding effects of these underlying conditions when interpreting the association between cesarean delivery and asphyxia. While the current study adjusted for several potential confounders, it is possible that residual confounding remains, and further research is needed to fully elucidate the independent contribution of cesarean section to asphyxia risk. The findings of this study should not be interpreted as a condemnation of cesarean section, which remains a life-saving procedure in many situations. However, they do highlight the importance of carefully considering the potential risks and benefits of cesarean delivery, particularly in the context of neonatal respiratory outcomes. The decision to perform a cesarean section should be based on clear medical indications and individualized risk assessment, weighing the potential benefits against the potential risks for both mother and newborn. Efforts should also be made to optimize the management of cesarean deliveries to minimize the risk of asphyxia. This may include strategies such as delayed cord clamping, gentle handling of the newborn, and prompt initiation of respiratory support when needed. Additionally, further research is warranted to explore potential interventions that could mitigate the respiratory complications associated with cesarean section, such as the use of antenatal corticosteroids or alternative anesthetic techniques.[11,12]

The strong association between low birth weight (LBW) and asphyxia observed in this study aligns with a wealth of existing literature that underscores the heightened vulnerability of LBW infants to various complications, including respiratory distress and asphyxia. The study's findings serve as a stark reminder of the critical importance of addressing the underlying causes of LBW and providing specialized care to these newborns to mitigate the risk of asphyxia and its associated morbidities. The immature respiratory system of LBW infants is a central contributor to their susceptibility to asphyxia. The lungs of these newborns, particularly those born prematurely, are often underdeveloped and ill-equipped to handle the demands of extrauterine respiration. Surfactant, a complex mixture of lipids and proteins produced by specialized lung cells, plays a crucial role in reducing surface tension within the alveoli, the tiny air sacs where gas exchange occurs. This reduction in surface tension prevents alveolar collapse during exhalation, ensuring efficient oxygen uptake and carbon dioxide removal. Premature infants often have insufficient surfactant production due to the immaturity of their lungs. This deficiency can lead to respiratory distress syndrome (RDS), a condition characterized by widespread alveolar collapse (atelectasis) and impaired gas exchange. The resulting hypoxia and hypercapnia can rapidly progress to asphyxia if not promptly recognized and managed. In addition to surfactant deficiency, LBW infants often have underdeveloped lung tissue, with fewer and smaller alveoli. This structural immaturity further compromises their respiratory capacity by reducing the surface area available for gas exchange. The decreased number and size of alveoli also make the lungs more prone to collapse, exacerbating the challenges of maintaining adequate oxygenation. The respiratory muscles of LBW infants, including the diaphragm and intercostal muscles, are often weak and less efficient, hindering their ability to generate adequate inspiratory and expiratory forces. Furthermore, the respiratory control centers in the brainstem, responsible for regulating the rhythm and

depth of breathing, may be immature and less responsive to changes in blood oxygen and carbon dioxide levels. These factors can lead to irregular breathing patterns, apnea (periods of cessation of breathing), and an overall decreased ability to maintain adequate ventilation. LBW infants, particularly those born prematurely, have immature immune systems that make them more susceptible to infections. Respiratory infections, such as pneumonia and bronchiolitis, can further compromise their respiratory function by causing inflammation and obstruction of the airways. This can lead to increased work of breathing, decreased oxygenation, and an elevated risk of asphyxia. It is important to recognize that low birth weight is not a homogenous entity but rather a manifestation of various underlying factors. Premature birth, defined as birth before 37 weeks of gestation, is a major contributor to LBW. Preterm infants are born before their organs, including the lungs, have fully matured, making them particularly vulnerable to respiratory complications and asphyxia. Intrauterine growth restriction (IUGR), another significant cause of LBW, occurs when the fetus fails to achieve its genetically predetermined growth potential due to various factors, such as placental insufficiency, maternal malnutrition, or chronic diseases. IUGR can lead to a cascade of adverse effects on fetal development, including impaired lung growth and maturation, further increasing the risk of asphyxia. The strong association between LBW and asphyxia underscores the critical importance of prenatal care and interventions aimed at preventing preterm birth and promoting optimal fetal growth. Early identification and management of maternal conditions that can lead to LBW, such as preeclampsia, gestational diabetes, and infections, are crucial for improving neonatal outcomes. Adequate maternal nutrition, smoking cessation, and avoidance of alcohol and illicit drugs during pregnancy are also essential for promoting healthy fetal growth and development. In cases where preterm birth or IUGR is unavoidable, antenatal corticosteroids can be administered to the mother to accelerate fetal lung maturation and reduce the risk of RDS and other respiratory complications. This intervention has been shown to significantly improve neonatal outcomes, including a reduction in the incidence of asphyxia. The provision of specialized care and respiratory support for LBW infants is paramount for minimizing the risk of asphyxia and its associated complications. Neonatal intensive care units (NICUs) equipped with advanced technology and staffed by trained healthcare professionals are essential for providing the comprehensive care that these vulnerable newborns require. Respiratory support may include supplemental oxygen, continuous positive airway pressure (CPAP), or mechanical ventilation, depending on the severity of the respiratory distress. Surfactant replacement therapy can also be administered to premature infants with RDS to improve lung function and reduce the need for mechanical ventilation. In addition to respiratory support, LBW infants require careful monitoring and management of other potential complications, such as hypothermia, hypoglycemia, and infections. Early initiation of breastfeeding or provision of fortified human milk or formula is crucial for promoting growth and development. The impact of asphyxia and LBW can extend beyond the neonatal period, with potential long-term consequences for neurodevelopment and overall health. LBW infants are at increased risk of developing cerebral palsy, intellectual disability, and other neurodevelopmental disabilities. They may also experience growth delays, visual and hearing impairments, and chronic health conditions such as asthma and chronic lung disease. Therefore, long-term follow-up and early intervention programs are essential for optimizing the outcomes of LBW infants who have experienced asphyxia. These programs should focus on monitoring growth and development, providing appropriate therapies and interventions, and supporting families in navigating the challenges associated with caring for a child with

special needs. The burden of LBW and asphyxia is disproportionately high in LMICs, where access to quality prenatal care and specialized neonatal care is often limited. Public health initiatives aimed at improving maternal and child health in these settings are crucial for reducing the incidence of LBW and asphyxia and improving neonatal outcomes. These initiatives should focus on strengthening prenatal care programs, promoting skilled birth attendance, and ensuring the availability of neonatal resuscitation equipment and trained personnel in all healthcare settings. Community-based interventions aimed at raising awareness about the risk factors for LBW and asphyxia and the importance of seeking timely medical care can also play a crucial role in reducing the burden of these conditions.[13,14]

While the study identified cesarean section and low birth weight as the primary independent predictors of asphyxia, it is crucial to acknowledge that neonatal asphyxia is a multifaceted condition with a complex etiology. It arises from an intricate interplay of maternal, fetal, and placental factors, often acting in concert to compromise the newborn's respiratory adaptation. The non-significant association of gestational age in the multivariate analysis suggests that its impact on asphyxia risk might be mediated through other variables, such as low birth weight, which is frequently associated with preterm birth. Maternal health and well-being during pregnancy play a pivotal role in determining neonatal outcomes. This hypertensive disorder of pregnancy can lead to placental insufficiency, reducing blood flow and oxygen delivery to the fetus. The resulting fetal hypoxia and acidosis can predispose the newborn to asphyxia. Poorly controlled maternal diabetes can lead to macrosomia (large fetal size), which can complicate labor and delivery, increasing the risk of birth trauma and asphyxia. Additionally, infants of diabetic mothers may experience hypoglycemia after birth, which can further compromise their respiratory function. Maternal infections, particularly those affecting the amniotic fluid and placenta, can trigger an inflammatory response that can impair fetal oxygenation and lead to asphyxia. The health and development of the fetus itself are also critical determinants of asphyxia risk. Structural abnormalities affecting the heart, lungs, or central nervous system can impair the newborn's ability to initiate and maintain effective respiration, increasing the risk of asphyxia. FGR, characterized by a fetus that is smaller than expected for its gestational age, can result from various factors, including placental insufficiency and maternal malnutrition. FGR can lead to impaired fetal oxygenation and acidosis, predisposing the newborn to asphyxia.[15,16]

The placenta, the lifeline between mother and fetus, plays a vital role in fetal oxygenation and nutrient delivery. Disruptions in placental function can have profound consequences for the newborn's well-being. This condition occurs when the placenta separates from the uterine wall prematurely, disrupting blood flow and oxygen delivery to the fetus. The resulting fetal hypoxia and acidosis can rapidly progress to asphyxia. Problems with the umbilical cord, such as nuchal cord (cord wrapped around the neck) or cord prolapse (cord descends into the birth canal before the baby), can impede blood flow and oxygen delivery to the fetus, increasing the risk of asphyxia. The events surrounding labor and delivery can also significantly impact neonatal outcomes. A protracted labor can lead to fetal exhaustion and distress, increasing the risk of asphyxia. This occurs when the fetus is unable to descend through the birth canal due to a mechanical obstruction, such as a disproportion between the fetal head and the maternal pelvis. Obstructed labor can lead to prolonged compression of the umbilical cord, compromising fetal oxygenation and increasing the risk of asphyxia. Meconium, the first stool passed by the newborn, can be released into the amniotic fluid during fetal distress. If aspirated into the lungs, meconium can cause airway obstruction and inflammation, leading to

respiratory distress and asphyxia. The complex interplay of these maternal, fetal, placental, and intrapartum factors underscores the need for a comprehensive approach to preventing and managing asphyxia. Regular prenatal care allows for early identification and management of maternal and fetal risk factors for asphyxia. This includes screening for conditions such as preeclampsia, diabetes, and infections, as well as monitoring fetal growth and development. Prenatal education and counseling can also empower women to make informed decisions about their pregnancy and childbirth, potentially reducing the risk of complications. The presence of skilled birth attendants during labor and delivery is crucial for ensuring the safe and timely management of potential complications, including those that can lead to asphyxia. Skilled birth attendants can recognize signs of fetal distress, perform necessary interventions, and initiate neonatal resuscitation when needed. The availability of neonatal resuscitation equipment and trained personnel is critical for ensuring prompt and effective management of asphyxia at birth. Neonatal resuscitation involves a series of steps aimed at establishing and maintaining adequate respiration and circulation in the newborn. Timely and effective resuscitation can significantly improve outcomes for newborns with asphyxia.[17,18]

The burden of neonatal asphyxia is disproportionately high in low- and middle-income countries (LMICs), where access to quality prenatal care and specialized neonatal care is often limited. Investments in health infrastructure, human resources, and essential medical supplies are needed to improve the quality and availability of maternal and newborn care in LMICs. This includes training more skilled birth attendants, equipping healthcare facilities with neonatal resuscitation equipment, and establishing referral systems for high-risk pregnancies and newborns. Community-based programs can play a vital role in raising awareness about the risk factors for asphyxia and promoting healthy behaviors during pregnancy and childbirth. These programs can also empower communities to identify and address barriers to accessing care, such as transportation challenges and cultural beliefs. Continued research is needed to better understand the complex etiology of asphyxia and develop innovative interventions for prevention and management. This includes research on the underlying pathophysiological mechanisms, the effectiveness of various interventions, and the long-term outcomes of newborns with asphyxia. The findings of this study carry significant implications for both clinical practice and public health initiatives aimed at reducing the burden of neonatal asphyxia. The identification of cesarean section and low birth weight as independent risk factors underscores the need for targeted interventions and heightened vigilance in these specific populations. The strong association between cesarean section and asphyxia emphasizes the need for judicious decision-making regarding delivery mode. While cesarean section is undeniably a life-saving procedure in certain situations, it is not without risks. The potential impact on neonatal respiratory adaptation should be carefully considered. The decision to perform a cesarean section should be based on clear medical indications and individualized risk assessment, weighing the potential benefits against the potential risks for both mother and newborn. The identification of low birth weight as a significant predictor of asphyxia highlights the importance of specialized care and respiratory support for these vulnerable newborns. Neonatal intensive care units (NICUs) equipped with advanced technology and staffed by trained healthcare professionals are essential for providing the comprehensive care that these infants require. Early identification and management of maternal conditions that can lead to low birth weight, such as preeclampsia and gestational diabetes, are crucial for improving neonatal outcomes. Prenatal care plays a crucial role in identifying and addressing maternal and fetal risk factors for asphyxia. Healthcare providers should engage in

comprehensive prenatal counseling and education, emphasizing the importance of healthy behaviors during pregnancy, such as maintaining a balanced diet, avoiding smoking and alcohol, and seeking timely medical attention for any concerns. Empowering women to make informed decisions about their pregnancy and childbirth can contribute to reducing the risk of complications, including asphyxia. The presence of skilled birth attendants during labor and delivery is paramount for ensuring the safe and timely management of potential complications. These healthcare professionals can recognize signs of fetal distress, perform necessary interventions, and initiate neonatal resuscitation when needed. Ensuring the availability of skilled birth attendants in all healthcare settings, particularly in resource-limited areas, is crucial for reducing neonatal mortality and morbidity associated with asphyxia. The availability of neonatal resuscitation equipment and trained personnel is critical for ensuring prompt and effective management of asphyxia at birth. Healthcare providers at all levels should receive adequate training in neonatal resuscitation techniques to ensure that they can respond effectively to emergencies and improve neonatal outcomes. Public health initiatives should focus on improving access to quality prenatal care for all women, regardless of their socioeconomic status. This includes expanding the reach of antenatal care services, increasing the frequency of visits, and providing comprehensive screening and management of maternal and fetal risk factors for asphyxia. Efforts should be made to promote skilled birth attendance at all deliveries, particularly in rural and underserved areas. This may involve training more midwives and other healthcare professionals in essential obstetric and neonatal care skills, as well as addressing barriers to accessing skilled birth attendance, such as transportation challenges and cultural beliefs. Public health programs should focus on strengthening neonatal resuscitation capacity in all healthcare settings. This includes ensuring the availability of essential equipment, providing training to healthcare providers, and establishing quality improvement initiatives to monitor and evaluate resuscitation practices. Community-based interventions can play a vital role in raising awareness about the risk factors for asphyxia and promoting healthy behaviors during pregnancy and childbirth. These interventions can also empower communities to identify and address barriers to accessing care, such as transportation challenges and cultural beliefs. Engaging community health workers and traditional birth attendants in these efforts can be particularly effective in reaching marginalized populations. The burden of neonatal asphyxia is often intertwined with broader social and economic inequities. Addressing the social determinants of health, such as poverty, malnutrition, and lack of education, is crucial for improving maternal and child health outcomes. Public health initiatives should focus on creating a supportive environment that enables all women to have healthy pregnancies and safe deliveries. Continued research is essential for advancing our understanding of the complex etiology of asphyxia and developing innovative interventions for prevention and management. Further investigation is needed to elucidate the precise pathophysiological mechanisms linking cesarean section, low birth weight, and other risk factors to asphyxia. This knowledge can inform the development of targeted interventions to mitigate the risks associated with these factors. Rigorous evaluation of existing and novel interventions is crucial for determining their effectiveness in reducing the burden of asphyxia. This includes assessing the impact of prenatal care programs, skilled birth attendance initiatives, and neonatal resuscitation training programs on asphyxia rates and neonatal outcomes. Research on the long-term neurodevelopmental and health outcomes of newborns with asphyxia is essential for understanding the full impact of this condition and developing effective rehabilitation strategies.[19,20]

4. Conclusion

This case-control study conducted at Salatiga Regional General Hospital identified cesarean section and low birth weight as independent predictors of neonatal asphyxia. These findings highlight the importance of careful consideration in delivery mode selection and the need for specialized care for low birth weight infants. While premature rupture of membranes and gestational age showed associations with asphyxia in bivariate analysis, they were not found to be independent predictors in the multivariate model. This study contributes valuable insights into the complex etiology of neonatal asphyxia and emphasizes the need for targeted interventions to reduce its burden, particularly in low- and middle-income countries. Further research is warranted to explore the underlying mechanisms and develop effective preventive and management strategies.

5. References

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