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NEURODEVELOPMENTAL OUTCOMES FOLLOWING PERINATAL ASPHYXIA AMONG CHILDREN ATTENDING SHEIKHAN GENERAL HOSPITAL, NINEVEH, IRAQ

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ABSTRACT

Background: Perinatal asphyxia is a major cause of neonatal morbidity and mortality worldwide and remains an important contributor to long-term neurological disability among survivors. Children affected by perinatal asphyxia are at increased risk of developmental delay, cerebral palsy, seizure disorders, hearing impairment, and other neurodevelopmental abnormalities. Early identification of these outcomes is essential for timely intervention and improved long-term prognosis. **Objectives:** To evaluate the neurodevelopmental outcomes of children with a history of perinatal asphyxia attending Sheikhan General Hospital and to identify factors associated with adverse neurodevelopmental outcomes. **Methods:** This retrospective cohort study was conducted at Sheikhan General Hospital, Nineveh Governorate, Iraq, from July 2024 to March 2026. A total of 76 children with a documented history of perinatal asphyxia were included. Data were collected from neonatal records, hospital files, and follow-up clinic records. Demographic characteristics, neonatal variables, severity of perinatal asphyxia, presence of hypoxic-ischemic encephalopathy, and neurodevelopmental outcomes were analyzed. Statistical analysis was performed using SPSS version 31. Associations between clinical variables and adverse neurodevelopmental outcomes were assessed using Chi-square and multivariate logistic regression analyses. A P value of less than 0.05 was considered statistically significant. **Results:** Male children constituted 57.9% of the study population, and 35.5% had low birth weight. Hypoxic-ischemic encephalopathy was documented in 43.4% of patients. Moderate and severe perinatal asphyxia accounted for 44.7% and 21.1% of cases, respectively. Normal neurodevelopment was observed in 67.1% of children, whereas adverse neurodevelopmental outcomes occurred in 32.9%. Developmental delay was the most common abnormal outcome (18.4%), followed by cerebral palsy (9.2%), seizure disorders (7.9%), and hearing impairment (5.3%). Adverse outcomes were significantly associated with severe perinatal asphyxia ($P < 0.001$), low birth weight ($P = 0.002$), hypoxic-ischemic encephalopathy ($P < 0.001$), and low Apgar scores ($P = 0.001$). Multivariate logistic regression analysis identified severe perinatal asphyxia (OR = 5.84, 95% CI: 1.76–19.34, $P = 0.004$), hypoxic-ischemic encephalopathy (OR = 4.23, 95% CI: 1.39–12.86, $P = 0.011$), and low birth weight (OR = 3.17, 95% CI: 1.08–9.28, $P = 0.036$) as independent predictors of adverse neurodevelopmental outcomes. **Conclusions:** Perinatal asphyxia remains an important cause of neurodevelopmental impairment among children. Developmental delay was the most frequent neurological sequela, and severe perinatal asphyxia, hypoxic-ischemic encephalopathy, and low birth weight were the strongest predictors of adverse neurodevelopmental outcomes. Regular developmental follow-up, early rehabilitation programs, and improvements in neonatal resuscitation and perinatal care are essential to reduce long-term disability and improve quality of life among affected children.

KEYWORDS: Cerebral palsy, Developmental delay, Hypoxic-ischemic encephalopathy, Neurodevelopmental outcomes, Perinatal asphyxia, Seizure disorders.

1-INTRODUCTION

Perinatal asphyxia is one of the leading causes of neonatal morbidity and mortality worldwide and remains a major public health concern, particularly in developing countries. It is defined as the inability of a newborn infant to initiate and sustain adequate respiration immediately after birth, resulting in impaired oxygen delivery to vital organs and tissues. The condition may lead to hypoxemia, hypercapnia, metabolic acidosis, and multi-organ dysfunction. Despite advances in obstetric and neonatal care, perinatal asphyxia continues to contribute substantially to neonatal deaths and long-term neurological disabilities among survivors.[1]

Globally, birth asphyxia accounts for a significant proportion of neonatal mortality and is estimated to be responsible for nearly one million neonatal deaths annually. In addition to mortality, survivors of perinatal asphyxia frequently experience a variety of neurological complications that may persist throughout childhood and adulthood. These complications place a considerable burden on healthcare systems and families, particularly in low-resource settings where access to specialized neonatal care and rehabilitation services may be limited.[2]

The pathophysiological effects of perinatal asphyxia are primarily related to hypoxic-ischemic injury. During episodes of oxygen deprivation, blood flow is preferentially redistributed to vital organs such as the brain, heart, and adrenal glands. However, prolonged or severe hypoxia overwhelms these compensatory mechanisms and results in cellular injury, energy depletion, inflammation, and neuronal death. The brain is particularly vulnerable to hypoxic-ischemic damage because of its high metabolic requirements, making neurological impairment one of the most serious consequences of perinatal asphyxia.[3]

Hypoxic-ischemic encephalopathy (HIE) represents the most important neurological manifestation of perinatal asphyxia and is a major predictor of long-term neurodevelopmental disability. The severity of HIE is closely associated with subsequent neurological outcomes, with severe cases carrying the highest risk of cerebral palsy, epilepsy, intellectual disability, hearing impairment, visual deficits, and developmental delay. Early diagnosis and appropriate neonatal management are therefore essential to improve survival and reduce neurological sequelae.[4]

Several maternal, fetal, and intrapartum factors have been identified as risk factors for perinatal asphyxia. These include maternal hypertension, diabetes mellitus, prolonged labor, placental insufficiency, meconium aspiration, umbilical cord complications, fetal distress, prematurity, and low birth weight. Recognition and management of these risk factors during pregnancy and delivery may contribute significantly to reducing the incidence and severity of birth asphyxia.[5]

Neurodevelopment refers to the progressive acquisition of motor, cognitive, language, social, and adaptive skills throughout infancy and childhood. Children who survive perinatal asphyxia may exhibit varying degrees of neurodevelopmental impairment, ranging from subtle learning difficulties to severe neurological disabilities. Developmental delays may affect gross and fine motor functions, speech and language development, cognitive performance, behavior, and social interaction. Consequently, long-term follow-up and developmental assessment are important components of post-asphyxia care.[6]

Several studies have demonstrated that adverse neurodevelopmental outcomes are more common among children with severe perinatal asphyxia, low Apgar scores, prolonged resuscitation, and hypoxic-ischemic encephalopathy. The incidence and severity of developmental impairment vary according to the degree of brain injury and the effectiveness of neonatal management. Early identification of developmental abnormalities allows timely intervention, which may improve functional outcomes and quality of life.[7]

Perinatal asphyxia remains an important cause of neonatal morbidity and mortality in Iraq and may result in long-term neurological and developmental disabilities among survivors. However, information regarding neurodevelopmental outcomes in affected children is limited, particularly in Nineveh Governorate. Therefore, this study was conducted to evaluate the neurodevelopmental outcomes of children with a history of perinatal asphyxia attending Sheikhan General Hospital and to identify factors associated with adverse neurodevelopmental outcomes.

2-PATIENTS AND METHODS

Prior to data collection, approval for the study was obtained from the relevant ethical and scientific authorities of Nineveh Health Directorate. All patient information was handled with strict confidentiality, and personal identifiers were omitted during data analysis to ensure privacy. The collected data were used exclusively for academic and research purposes. This retrospective cohort study was conducted at Sheikhan General Hospital, Nineveh Governorate, Iraq, to evaluate the neurodevelopmental outcomes of children with a history of perinatal asphyxia. The study period extended from July 1, 2024, to March 31, 2026. A total of 76 children diagnosed with perinatal asphyxia during the neonatal period and subsequently followed up in pediatric outpatient clinics were included in the study.

Patients were identified through a review of neonatal admission records, delivery records, pediatric outpatient clinic files, and hospital medical records. Perinatal asphyxia was diagnosed based on failure to initiate and sustain adequate respiration at birth, low Apgar scores, need for neonatal resuscitation, and clinical evidence of

hypoxic-ischemic injury documented in the medical records.

Children with complete follow-up records and documented developmental assessments were eligible for inclusion. Patients with major congenital anomalies, chromosomal abnormalities, metabolic disorders, congenital neurological disorders, or incomplete medical records were excluded from the study.

Data collected included maternal and demographic characteristics such as maternal age, parity, antenatal care status, pregnancy complications, mode of delivery, and gestational age. Neonatal variables included sex, birth weight, Apgar score at 5 minutes, severity of perinatal asphyxia, presence of hypoxic-ischemic encephalopathy, duration of neonatal intensive care unit admission, and need for resuscitation.

Neurodevelopmental outcomes were assessed during follow-up visits and included motor development, language development, cognitive development, seizure disorders, cerebral palsy, hearing impairment, and overall developmental status. Outcomes were classified as either normal neurodevelopment or adverse neurodevelopmental outcome, which included developmental delay, cerebral palsy, epilepsy, hearing impairment, or multiple neurological deficits.

Data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS) version 31. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Associations between clinical variables and neurodevelopmental outcomes were evaluated using the Chi-square test or Fisher's exact test where appropriate. Multivariate logistic regression analysis was performed to identify independent predictors of adverse neurodevelopmental outcomes. A P value of less than 0.05 was considered statistically significant.

3-RESULTS

A total of 76 children with a documented history of perinatal asphyxia who attended Sheikhan General Hospital during the study period were included in this study. Table 1 presents the demographic and neonatal characteristics of the studied children with a history of perinatal asphyxia. Male children constituted 57.9% of the study population, while females accounted for 42.1%, resulting in a male-to-female ratio of approximately 1.4:1. Most children were delivered by cesarean section (65.8%), whereas vaginal delivery was reported in 34.2% of cases. Preterm birth was documented in 30.3% of patients, while 35.5% had low birth weight. These findings indicate that male sex, cesarean delivery, and low birth weight were common characteristics among children with perinatal asphyxia included in the study.

Table 1: Demographic and neonatal characteristics of the studied children (n=76).

Variable	Number (%)
Male	44 (57.9%)
Female	32 (42.1%)
Cesarean section	50 (65.8%)
Vaginal delivery	26 (34.2%)
Preterm birth	23 (30.3%)
Term birth	53 (69.7%)
Low birth weight	27 (35.5%)

Table 2 demonstrates the neonatal clinical characteristics of the studied patients. More than half of the neonates (56.6%) had Apgar scores between 4 and 6 at five minutes, while 27.6% had severe depression with Apgar scores below 4. Hypoxic-ischemic encephalopathy (HIE) was diagnosed in 43.4% of patients, reflecting the significant neurological impact of perinatal asphyxia. Prolonged neonatal intensive care unit admission exceeding seven days was observed in 38.2% of neonates, and 32.9% required advanced resuscitative measures at birth. These findings indicate that a considerable proportion of patients experienced significant neonatal compromise.

Table 2: Clinical characteristics of neonates with perinatal asphyxia (n=76).

Variable	Number (%)
Apgar <4	21 (27.6%)
Apgar 4–6	43 (56.6%)
Apgar >6	12 (15.8%)
HIE	33 (43.4%)
NICU >7 days	29 (38.2%)
Advanced resuscitation	25 (32.9%)

Table 3 shows the distribution of patients according to the severity of perinatal asphyxia. Moderate perinatal asphyxia represented the largest group, accounting for 44.7% of cases, followed by mild asphyxia in 34.2%. Severe perinatal asphyxia was observed in 21.1% of patients. These findings suggest that although most children experienced mild-to-moderate disease, a substantial proportion suffered severe asphyxia, which may have influenced subsequent neurodevelopmental outcomes.

Table 3: Severity of perinatal asphyxia (n=76).

Severity	Number (%)
Mild	26 (34.2%)
Moderate	34 (44.7%)
Severe	16 (21.1%)

Table 4 presents the neurodevelopmental outcomes observed during follow-up. Normal neurodevelopment was achieved in 67.1% of children, whereas adverse neurodevelopmental outcomes were identified in approximately one-third of patients. Developmental delay was the most common abnormal outcome, affecting 18.4% of children, followed by cerebral palsy

(9.2%), seizure disorders (7.9%), and hearing impairment (5.3%). These findings highlight the significant burden of neurological sequelae among survivors of perinatal asphyxia.

Table 4: Neurodevelopmental outcomes (n=76).

Outcome	Number (%)
Normal neurodevelopment	51 (67.1%)
Developmental delay	14 (18.4%)
Cerebral palsy	7 (9.2%)
Seizure disorder	6 (7.9%)
Hearing impairment	4 (5.3%)

Table 5 demonstrates the relationship between the severity of perinatal asphyxia and neurodevelopmental outcomes. Adverse neurodevelopmental outcomes were observed in only 11.5% of children with mild asphyxia compared with 29.4% of those with moderate asphyxia and 75.0% of those with severe asphyxia. Conversely, normal neurodevelopment was most frequently observed among children with mild disease. The association between asphyxia severity and neurodevelopmental outcome was highly statistically significant ($P < 0.001$), indicating that increasing severity of perinatal asphyxia is associated with a markedly increased risk of neurological impairment.

Table 5: Severity of asphyxia and neurodevelopmental outcomes.

Severity	Adverse n(%)	Normal n(%)	P value
Mild	3 (11.5%)	23 (88.5%)	**<0.001**
Moderate	10 (29.4%)	24 (70.6%)	
Severe	12 (75.0%)	4 (25.0%)	

Table 6 shows the relationship between selected neonatal factors and adverse neurodevelopmental outcomes. Children with low birth weight demonstrated significantly higher rates of adverse outcomes than those with normal birth weight (55.6% versus 20.4%, $P = 0.002$). Similarly, adverse outcomes were significantly more frequent among patients with hypoxic-ischemic encephalopathy compared with those without HIE (54.5% versus 16.3%, $P < 0.001$). Children with Apgar scores below 4 also experienced significantly higher rates of neurological impairment than those with higher Apgar scores (61.9% versus 21.8%, $P = 0.001$). These findings suggest that low birth weight, severe birth depression, and HIE are important risk factors for poor neurodevelopmental outcomes.

Table 6: Neonatal factors associated with adverse outcomes.

Variable	Adverse n(%)	Normal n(%)	P value
Low birth weight	15 (55.6%)	12 (44.4%)	**0.002**
Normal birth weight	10 (20.4%)	39 (79.6%)	
HIE present	18 (54.5%)	15 (45.5%)	**<0.001**
HIE absent	7 (16.3%)	36 (83.7%)	
Apgar <4	13 (61.9%)	8 (38.1%)	**0.001**

Table 7 presents the results of multivariate logistic regression analysis performed to identify independent predictors of adverse neurodevelopmental outcomes. Severe perinatal asphyxia was identified as the strongest predictor, increasing the risk of adverse outcome by approximately 5.8 times (OR = 5.84, 95% CI: 1.76–19.34, $P = 0.004$). The presence of hypoxic-ischemic encephalopathy was associated with a more than fourfold increase in risk (OR = 4.23, 95% CI: 1.39–12.86, $P = 0.011$), while low birth weight increased the risk by approximately threefold (OR = 3.17, 95% CI: 1.08–9.28, $P = 0.036$). Although preterm birth showed an increased risk, it did not reach statistical significance after adjustment for other variables ($P = 0.221$). These findings indicate that severe perinatal asphyxia, hypoxic-ischemic encephalopathy, and low birth weight are the most important independent predictors of adverse neurodevelopmental outcomes.

Table 7: Multivariate logistic regression analysis.

Variable	OR	95% CI	P value
Severe perinatal asphyxia	5.84	1.76–19.34	**0.004**
HIE	4.23	1.39–12.86	**0.011**
Low birth weight	3.17	1.08–9.28	**0.036**
Preterm birth	1.94	0.67–5.58	0.221

4- DISCUSSION

History of perinatal asphyxia attending Sheikhan General Hospital and identified factors associated with adverse neurological outcomes. The findings demonstrated that approximately one-third of the studied children developed neurodevelopmental impairment, with developmental delay being the most common abnormal outcome. Furthermore, severe perinatal asphyxia, hypoxic-ischemic encephalopathy (HIE), and low birth weight were identified as significant predictors of adverse neurodevelopmental outcomes.

In the current study, male children constituted 57.9% of the study population, slightly exceeding the proportion of female children. Similar observations have been reported in previous neonatal study, which demonstrated a modest male predominance among infants affected by perinatal asphyxia and related neurological complications. This finding may reflect differences in neonatal susceptibility to hypoxic-ischemic injury and other perinatal stressors.[8]

The majority of children in the present study were delivered by cesarean section. This finding may be explained by the increased frequency of fetal distress and obstetric complications requiring emergency operative

delivery. Similar observations were reported by **Badawi *et al***., who found that fetal distress and emergency cesarean section are commonly associated with neonatal encephalopathy and perinatal asphyxia.[9]

Hypoxic-ischemic encephalopathy was documented in 43.4% of the studied patients. This finding reflects the substantial neurological burden associated with perinatal asphyxia and is consistent with the pathophysiological mechanisms described by **Volpe**, who emphasized that hypoxic-ischemic brain injury remains the principal cause of long-term neurological sequelae among survivors of birth asphyxia.[10]

The present study demonstrated that normal neurodevelopment was achieved in 67.1% of children during follow-up, while adverse neurodevelopmental outcomes occurred in 32.9% of cases. Developmental delay was the most common abnormal outcome, followed by cerebral palsy, seizure disorders, and hearing impairment. These findings are consistent with the observations of **Azzopardi *et al***., who reported that survivors of perinatal asphyxia remain at increased risk of developmental delay and neurological disability despite improvements in neonatal management.[11]

Developmental delay was identified in 18.4% of the studied children and represented the most frequent neurodevelopmental impairment. Similar findings were reported by **Robertson and Perlman**, who observed that developmental and cognitive deficits are among the most common long-term consequences of neonatal hypoxic-ischemic injury and may become increasingly apparent during infancy and early childhood.[12]

Cerebral palsy was observed in 9.2% of patients in the current study. This finding is comparable to results reported by **Shankaran *et al***., who demonstrated a significant association between severe perinatal asphyxia and subsequent development of cerebral palsy, particularly among infants with hypoxic-ischemic encephalopath.[13]

A highly significant relationship was observed between the severity of perinatal asphyxia and neurodevelopmental outcomes. Children with severe perinatal asphyxia experienced substantially higher rates of developmental impairment compared with those with mild or moderate disease. Similar findings were reported by **Jacobs *et al***., who demonstrated that the severity of hypoxic injury is one of the strongest determinants of long-term neurological outcome.[14]

The present study also demonstrated a significant association between low birth weight and adverse neurodevelopmental outcomes. Children with low birth weight had significantly higher rates of neurological impairment than those with normal birth weight. This observation may be attributed to the increased vulnerability of the immature brain to hypoxic-ischemic injury. Similar findings were reported by **Laptook *et al***., who found that low birth weight and neonatal compromise significantly increase the risk of developmental disability.[15]

Hypoxic-ischemic encephalopathy emerged as another important predictor of adverse outcomes. Children with documented HIE experienced significantly higher rates of developmental impairment than those without HIE. Moreover, HIE remained an independent predictor in multivariate analysis. This finding is consistent with the work of **Sarnat and Sarnat**, who demonstrated a strong relationship between the severity of neonatal encephalopathy and subsequent neurological outcome.[16]

Low Apgar scores were also significantly associated with adverse neurodevelopmental outcomes in the present study. Children with Apgar scores below four had markedly higher rates of neurological impairment compared with those with higher scores. Similar observations were reported by **Nelson and Ellenberg**, who found that severely depressed Apgar scores are associated with an increased risk of cerebral palsy and developmental delay later in life.[17]

Multivariate logistic regression analysis identified severe perinatal asphyxia, hypoxic-ischemic encephalopathy, and low birth weight as independent predictors of adverse neurodevelopmental outcomes. Severe perinatal asphyxia was the strongest predictor, increasing the risk of neurological impairment by nearly sixfold. These findings emphasize the importance of early identification of high-risk infants and the implementation of intensive follow-up programs aimed at detecting developmental abnormalities at an early stage.

This study has several limitations that should be acknowledged. First, the retrospective design relied on the accuracy and completeness of hospital records, which may have resulted in missing or incomplete data. Second, the study was conducted at a single center and included a relatively small sample size of 76 patients, which may limit the generalizability of the findings to other populations. In addition, variations in the duration and quality of follow-up among patients may have influenced the assessment of neurodevelopmental outcomes. Some developmental abnormalities may not have become apparent during the study period, particularly those affecting higher cognitive and behavioral functions. Furthermore, socioeconomic factors, parental educational status, and access to rehabilitation services were not evaluated despite their potential influence on neurodevelopmental outcomes. Despite these limitations, the study provides valuable local data regarding the neurodevelopmental consequences of perinatal asphyxia and identifies important predictors of adverse neurological outcomes among affected children.

5- CONCLUSION AND RECOMMENDATION

The present study demonstrated that perinatal asphyxia remains an important cause of neurodevelopmental impairment among children. Although normal neurodevelopment was observed in the majority of patients, a considerable proportion developed adverse neurological outcomes, including developmental delay, cerebral palsy, seizure disorders, and hearing impairment. The severity of perinatal asphyxia was significantly associated with poor neurodevelopmental outcomes, and severe perinatal asphyxia, hypoxic-ischemic encephalopathy, and low birth weight were identified as independent predictors of adverse neurological sequelae. These findings emphasize the importance of early recognition and appropriate management of high-risk neonates to reduce long-term disability. It is recommended that infants with a history of perinatal asphyxia undergo regular neurodevelopmental follow-up and early developmental screening to facilitate timely intervention. Strengthening neonatal resuscitation services, improving perinatal care, and expanding access to rehabilitation and developmental support programs may contribute to better long-term outcomes. Further prospective multicenter studies with larger sample sizes and longer follow-up periods are recommended to evaluate long-term cognitive, behavioral, and functional outcomes among survivors of perinatal asphyxia.

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