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Evaluation of Management Approaches and Short-Term Outcomes of Neonatal Hypoxic-Ischemic Encephalopathy: A Study at Atbara Teaching Hospital NICU, Sudan

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Abstract

Background: Hypoxic-ischemic encephalopathy (HIE) is a leading cause of neonatal mortality and long-term neurodevelopmental impairment, especially in resource-limited settings. It arises due to inadequate oxygen and blood flow to the brain during the perinatal period.

Aim: To evaluate the management strategies and short-term clinical outcomes of neonates diagnosed with HIE at Atbara Teaching Hospital NICU, Sudan.

Methods: A hospital-based descriptive cross-sectional study was conducted. Data were collected retrospectively from medical records of neonates admitted with HIE using a structured checklist. The sampling method included all eligible neonates admitted during the study period.

Results: The case fatality rate among neonates with HIE was 38.2%. Mortality was significantly associated with prolonged NICU stays, neonatal sepsis, and low Apgar scores at birth. Management primarily involved basic interventions such as therapeutic hypothermia and mechanical ventilation. However, the absence of advanced monitoring tools like blood gas analyzers and cerebral function monitors limited accurate diagnosis and timely management.

Conclusion: Basic management strategies currently used at Atbara NICU are insufficient to significantly improve survival and short-term neurological outcomes in neonates with HIE. The limited availability of diagnostic tools and the lack of specialized equipment are major challenges affecting neonatal care quality.

Recommendations: To improve HIE outcomes, it is essential to equip NICUs with advanced monitoring and therapeutic devices, such as blood gas analyzers and hypothermia systems. Future efforts should also consider incorporating structured follow-up programs and enhancing staff training based on the clinical burden identified.

Keywords: Neonatal hypoxic-ischemic encephalopathy; Short-term outcomes; NICU management; Atbara Teaching Hospital; Sudan

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"تقييم أساليب التدبير والنتائج قصيرة المدى للاختناق الدماغي الناتج عن نقص الأكسجين لدى حديثي الولادة: دراسة في وحدة العناية المكثفة لحديثي الولادة بمستشفى عطبرة التعليمي، السودان."

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(تاريخ الاستلام: 12-03-2025؛ تاريخ القبول: 13-05-2025)

المقدمة: يُعَدّ اعتلال الدماغ الإقفاري الناتج عن نقص الأوكسجين أحد الأسباب الرئيسية لوفيات حديثي الولادة والاختلالات العصبية طويلة المدى، لا سيما في البيئات محدودة الموارد. ينشأ هذا الاضطراب نتيجة انخفاض الأوكسجين وتدفق الدم إلى الدماغ خلال الفترة المحيطة بالولادة.

الهدف: تقييم استر اتيجيات إدارة الحالة والنتائج السريرية قصيرة المدى للمواليد المصابين باعتلال الدماغ الإقفاري الناتج عن نقص الأوكسجين في وحدة العناية المركزة لحديثي الولادة بمستشفى عطبرة التعليمي، السودان.

ا**لمنهجية:** أُجريت در اسة وصفية مستعرضة قائمة على المستشفى. تم جمع البيانات بأثر رجعي من السجلات الطبية للمواليد الذين أُدخلوا بتشخيص اعتلال الدماغ الإقفاري الناتج عن نقص الأوكسجين باستخدام قائمة فحص منظمة. شملت العينة جميع المواليد المؤهلين خلال فترة الدراسة.

النتائج: بلغ معدل الوفيات بين المواليد المصابين باعتلال الدماغ الإقفاري الناتج عن نقص الأوكسجين حوالي 38.2%. وُجد ارتباط كبير بين الوفاة والإقامة المطولية في وحدة العناية المركزة، وإصابية المواليد بالإنتيان الوليدي، وانخفاض درجيات مقياس Apgar عند الولادة. شملت خطية العلاج بشكل أساسي التدخلات الأساسية مثل التبريد العلاجي والتهوية الميكانيكية. ومع ذلك، فإن غياب أدوات المراقبة المتقدمة مثل محللات غازات الدم وأجهزة مراقبة وظائف الدماغ، حدّ من دقية التشخيص وسرعة التدخل العلاجي.

الاستنتاج: الاستراتيجيات الأساسية المُستخدمة حاليًا في وحدة العناية المركزة لحديثي الولادة بمستشفى عطبرة غير كافية لتحسين معدلات البقاء على قيد الحياة والنتائج العصبية قصيرة المدى بشكل ملحوظ لدى حديثي الولادة المصابين باعتلال الدماغ الإقفاري الناتج عن نقص الأوكسجين. يُعد نقص أدوات التشخيص وغياب الأجهزة المتخصصة تحديات رئيسية تؤثر على جودة رعاية حديثي الولادة.

التوصيات: لتحسين نتائج حالات اعتلال الدماغ الإقفاري الناتج عن نقص الأوكسجين، من الضروري تزويد وحدات العناية المركزة لحديثي الولادة بالأدوات العلاجية وأجهزة المراقبة المتقدمة مثل محللات غازات الدم وأنظمة التبريد العلاجي. كما ينبغي في المستقبل إدخال برامج متابعة منظمة وتعزيز تدريب الكوادر استنادًا إلى العبء السريري المكتشف.

ا**لكلمات المفتاحية:** اعتلال الدماغ الإقفاري عند حديثي الولادة؛ النتائج قصيرة المدى؛ إدارة وحدة العناية المركزة؛ مستشفى عطبرة التعليمي؛ السودان.

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1. Introduction

Hypoxic-ischemic encephalopathy (HIE) is a significant cause of neonatal morbidity and mortality worldwide, particularly in low- and middle-income countries (LMICs) like Sudan(1). The condition arises from insufficient oxygen and blood flow to the neonatal brain during the perinatal period, leading to potential long-term neurological impairments(2).

In Sudan, healthcare facilities often face challenges such as limited resources and inadequate infrastructure. Atbara Teaching Hospital, serving as the primary neonatal care center for Atbara City and its surrounding regions, exemplifies these challenges. The hospital's neonatal intensive care unit (NICU) primarily relies on basic resuscitation techniques for managing HIE, lacking advanced interventions like therapeutic hypothermia and mechanical ventilation. This limitation may contribute to suboptimal outcomes for affected neonates.

Therapeutic hypothermia, involving controlled cooling of the neonate, has been shown to reduce inflammation and neuronal apoptosis, thereby improving neurological outcomes in infants with moderate to severe HIE(3). Additionally, mechanical ventilation ensures adequate oxygenation, crucial for neonates with compromised respiratory function (4). The absence of these interventions in settings like Atbara Teaching Hospital underscores the need for evaluating current management strategies.

Neonatal hypoxic-ischemic encephalopathy (HIE) remains a significant cause of neonatal morbidity and mortality worldwide, particularly in low- and middle-income countries (LMICs) like Sudan(5). The condition results from a lack of oxygen and blood flow to the infant's brain during the perinatal period, leading to potential long-term neurological deficits(6).

Therapeutic hypothermia (TH) has emerged as the standard neuroprotective treatment for moderate to severe HIE in term and near-term infants(7). By cooling the infant's body to 33–34°C within six hours of birth and maintaining this temperature for 72 hours, TH has been shown to reduce brain injury and improve survival rates(8).

A recent survey across Sub-Saharan Africa highlighted that TH is available in only 13 countries, predominantly in private healthcare settings(9). Facilities offering TH often have better access to supportive technologies like mechanical ventilation and electroencephalograms (EEGs), which are crucial for monitoring and managing HIE. This disparity underscores the need for the equitable distribution of resources to manage HIE effectively across different healthcare settings(10). In addition to TH, adjunctive therapies are being explored to enhance neuroprotection in HIE. Hyperbaric oxygen therapy (HBOT) has shown promise in reducing oxidative stress and inflammation, thereby improving neurological outcomes in neonates with HIE(11). A meta-analysis indicated that HBOT could be an effective supplementary treatment, although further large-scale studies are needed to confirm its efficacy.

The implementation of dedicated neonatal neurocritical care programs has also been associated with improved outcomes in HIE management(12). Such programs emphasize standardized protocols, early initiation of TH, and comprehensive monitoring, leading to reduced brain injury and shorter hospital stays. These findings suggest that structured care models can significantly enhance the quality of neonatal care in HIE cases(13).

In the context of Sudan, and specifically at Atbara Teaching Hospital, the management of HIE is hindered by resource constraints, including limited access to TH and mechanical ventilation(14). This situation mirrors challenges faced in other LMICs, where infrastructural limitations impede the adoption of evidence-based practices for HIE management. Addressing these gaps requires concerted efforts to improve healthcare infrastructure, train medical personnel, and implement standardized care protocols to enhance neonatal outcomes.

Given the high burden of hypoxic-ischemic encephalopathy (HIE) and the limited access to advanced neonatal interventions at Atbara Teaching Hospital, this study aims to evaluate current management practices and outcomes to identify areas for improvement in treating neonates with HIE in resource-constrained settings.

1.1 Significance of the Study

Hypoxic-ischemic encephalopathy (HIE) remains a significant contributor to neonatal morbidity and mortality, particularly in low-resource settings like Sudan. The Atbara Teaching Hospital, serving as the primary neonatal care center for Atbara City and its surrounding regions, exemplifies the challenges faced in managing HIE due to limited resources and infrastructure. This study aims to assess the current management approaches and short-term outcomes of neonates diagnosed with HIE at Atbara Teaching Hospital's NICU. By analyzing survival rates and associated complications, the study seeks to identify gaps in care and recommend strategies for improving neonatal outcomes in resource-limited settings. The findings are expected to inform healthcare policies and practices, contributing to enhanced neonatal care and reduced long-term disabilities associated with HIE.

1.2 Aim of the Study

This study aims to evaluate the management approaches and short-term outcomes of neonates diagnosed with hypoxic-ischemic encephalopathy (HIE) at Atbara Teaching Hospital's Neonatal Intensive Care Unit (NICU) in Sudan. By analysing current treatment protocols and associated neonatal outcomes, the research seeks to identify existing gaps in care and propose strategies to enhance clinical practices and improve survival rates in resource-limited settings.

1.3 Research question

- 1. What are the current management approaches for neonates diagnosed with hypoxic-ischemic encephalopathy (HIE) in the Neonatal Intensive Care Unit (NICU) at Atbara Teaching Hospital?
- 2. What are the short-term outcomes, including survival rates and complications, among neonates with HIE in the NICU at Atbara Teaching Hospital?
- **3.** What differences, if any, exist in the outcomes of neonates with HIE who receive advanced interventions (such as therapeutic hypothermia and mechanical ventilation) compared to those who receive only basic resuscitative care?

2. Methodology

2.1 Study Design:

This descriptive cross-sectional study was conducted to evaluate the management approaches and short-term outcomes of neonates diagnosed with hypoxic-ischemic encephalopathy (HIE) in the Neonatal Intensive Care Unit (NICU) at Atbara Teaching Hospital, Sudan. The study period spanned from January to September 2022. Neonates with HIE were monitored from NICU admission until discharge or death.

2.2 Study Area and Population:

Atbara Teaching Hospital, located in Atbara City, Sudan, serves as the primary healthcare facility for the region. The hospital's NICU, established in 2016, is equipped with basic amenities such as incubators, oxygen concentrators, and phototherapy units. However, it lacks advanced equipment like mechanical ventilators, therapeutic hypothermia devices, and blood gas analysers.

The study included 68 neonates diagnosed with HIE during the study period. Data were collected from mothers, healthcare providers, and the NICU team.

2.3 Inclusion and Exclusion Criteria:

- Inclusion Criteria: Neonates diagnosed with HIE during the study period.
- Exclusion Criteria: Newborns with major congenital malformations or chromosomal anomalies.

2.4 Sample Size:

A total of 68 neonates diagnosed with HIE were included in the study. A sample size of at least 60 participants is recommended for cross-sectional studies to ensure statistical reliability and representativeness.

2.5 Data Collection:

Structured questionnaires were employed during face-to-face interviews with mothers and healthcare providers. The questionnaires were administered by trained interviewers during scheduled sessions within the NICU to ensure consistency, confidentiality, and reliability of responses. Data collected included maternal characteristics, risk factors for HIE, resuscitation procedures, treatment protocols, and neonatal outcomes, such as survival, neurological improvement (as indicated by clinical signs and Apgar scores), length of NICU stay, and respiratory support requirements (including mechanical ventilation or Continuous Positive Airway Pressure [CPAP]).

2.6 Outcome Measures:

The outcome measures utilized in the study included:

- Mortality Rate: The Proportion of neonates who died during the study period.
- Neurological Improvement: Assessed through clinical signs and Apgar scores.
- Length of NICU Stay: Duration of hospitalization in the NICU.
- **Respiratory Support Needs:** Requirement for mechanical ventilation or CPAP.

2.7 Ethical Considerations

Ethical approval for the study was obtained from the Institutional Review Board of Atbara Teaching Hospital. Informed consent was obtained from the mothers of all participating neonates. Participation was voluntary, and confidentiality was maintained throughout the study. The study adhered to ethical principles, including respect for participants, minimizing harm, and ensuring the integrity of the research process.

2.8 Statistical Analysis

Data were analysed using SPSS software (version 25). Descriptive statistics, including frequencies, percentages, means, and standard deviations, were calculated to summarize the data. Chi-square tests were used to assess associations between categorical variables, and independent t-tests were employed to compare continuous variables between groups. A p-value of less than 0.05 was considered statistically significant.

Reliability and Validity

The reliability of the structured questionnaires was assessed using Cronbach's alpha coefficient, with a value of 0.85 indicating good internal consistency. The validity of the questionnaires was evaluated through expert review, ensuring content validity by consulting with neonatology specialists and paediatricians. Additionally, face validity was confirmed by pre-testing the questionnaires with a small sample of participants to ensure clarity and relevance.

3. Results

3.1 Management Practices

The study revealed that all neonates requiring resuscitation received initial management in the Neonatal Intensive Care Unit (NICU), with no resuscitation performed in the delivery room. This indicates a delay in initiating critical interventions during the early hours post-birth, potentially impacting neonatal outcomes. Basic life-sustaining measures implemented in the NICU included warmth, oxygen administration, suction, and bag-mask ventilation. However, only 36.8% of neonates received mechanical ventilation due to the limited availability of appropriate ventilatory support systems. These findings highlight significant gaps in neonatal care infrastructure, which may have adversely affected patient outcomes.

3.2 Short-Term Outcomes

The study reported a mortality rate of 38.2%, indicating that approximately 40% of neonates with HIE did not survive during hospitalization. This underscores the severity of HIE and its impact on neonatal survival, particularly in settings lacking advanced therapeutic interventions. Additionally, 48.5% of neonates required NICU stays exceeding 10 days, reflecting the prolonged nature of HIE and associated complications. While 70% of survivors showed some clinical improvement, many remained at high risk for long-term neurological issues, including cerebral palsy, seizures, and developmental delays.

Table 1 Neonatal Outcomes in Atbara NICU (January – September 2022)

| Outcome Measure | Frequency (%) |
|------------------------------------|---|
| Mortality Rate | 38.2 |
| Duration of NICU Stay > 10 days | 48.5 |
| Sepsis Present | 77.9 |
| Low Apgar Score (5 mins) | 56.5 |
| Neurological Recovery | The majority improved but were at risk for long-term complications. |

Table 1 presents outcomes for neonates with HIE at Atbara NICU from January to September 2022, with a 38.2% mortality rate, 48.5% of infants experiencing

NICU stays exceeding 10 days, 77.9% developing sepsis, and 56.5% recording low Apgar scores at 5 minutes. These results suggest that severe initial hypoxic injury and suboptimal resuscitation, as well as high infection rates, are likely to lead to increased mortality and longer hospital stays. While most survivors presented neurological improvement, the long-term risk of complications indicates the need for enhanced neuroprotective measures and improved infection control measures in this setting.

3.3 Complications:

Sepsis was prevalent in 77.9% of neonates, highlighting the increased susceptibility to infections in this population. The high incidence of sepsis may be attributed to compromised immune systems, extended hospitalizations, and invasive procedures. Furthermore, 56.5% of neonates had low Apgar scores at 5 minutes, a critical indicator of adverse outcomes such as elevated mortality rates and neurodevelopmental disorders. Notably, low Apgar scores were associated with higher case fatality rates, emphasizing the importance of effective neonatal resuscitation and monitoring.

Incidence of sepsis and low Apgar scores among neonates with HIE.



Sepsis Low Apgar Scores

Figure 1: Incidence of sepsis and low Apgar scores among neonates with HIE.

3.4 Maternal and Neonatal Risk Factors

Several maternal and neonatal risk factors were identified, including prolonged rupture of membranes (61.8%), meconium-stained liquor (47.1%), maternal infections (32.4%), and prolonged labour (82.4%). These factors contribute to intrauterine infections and fatal oxygenation compromise, underscoring the need for enhanced prenatal care and monitoring to mitigate HIE severity.

| Risk Factor | Frequency (%) |
|--------------------------------|---------------|
| Prolonged Rupture of Membranes | 61.8 |
| Meconium Stained Liquor | 47.1 |
| Maternal Infection | 32.4 |
| Prolonged Labour | 82.4 |

 Table 2: Maternal and Neonatal Risk Factors

Table 2 outlines several key maternal and neonatal risk factors associated with HIE. Prolonged rupture of membranes (61.8%) can increase the risk of intrauterine infection, compromising fetal oxygenation. Meconium-stained liquor (47.1%) is indicative of fetal distress, often resulting from hypoxia before or during labour. Maternal infections (32.4%) further heighten the risk by potentially inducing systemic inflammation and sepsis, which can adversely affect placental function and fetal oxygen supply. Prolonged labour (82.4%) heightens fetal stress and the risk of hypoxic events by extending uterine contractions that can impair blood flow, highlighting the need for improved prenatal care and monitoring to reduce HIE severity.

These results suggest that severe initial hypoxic injury, delayed resuscitation, and high infection rates are likely contributors to increased mortality and extended hospital stays. Although most survivors exhibited neurological improvement, the persistent risk of complications indicates a critical need for improved neuroprotective strategies and infection control measures in this setting.

4. Discussion

This study evaluated the management and early outcomes of neonates diagnosed with hypoxic-ischemic encephalopathy (HIE) at Atbara Teaching Hospital's Neonatal Intensive Care Unit (NICU). The primary aim was to assess current management practices, the efficacy of available interventions, and short-term outcomes in a resource-constrained setting.

HIE is a leading cause of neonatal morbidity and mortality, often resulting from insufficient blood and oxygen supply to the brain during labour and delivery(12). The condition can range from mild to severe, leading to serious neurological complications or death. Early identification and intervention are crucial for improving survival rates and preventing long-term developmental impairments (15). At Atbara Teaching Hospital, basic supportive measures such as oxygen supplementation, suctioning, and warming are routinely employed. However, advanced interventions like therapeutic hypothermia (TH) and mechanical ventilation are limited due to resource constraints. Only 36.8% of neonates requiring mechanical ventilation received it, highlighting a significant gap in care(16). Improving survival rates for these neonates significantly depends on early identification and management(17). A 2010 Cochrane review showed that initiating TH within 6 hours of birth for babies with moderate to severe HIE significantly decreased mortality and major disability from 61% to 46%(18). However, despite its proven efficacy, the implementation of TH in low- and middle-income countries (LMICs) like Sudan remains limited due to resource constraints.

Mechanical ventilation is another critical component in the management of HIE, especially for neonates experiencing respiratory failure. The limited availability of ventilators in Atbara Teaching Hospital hampers the ability to provide adequate respiratory support, potentially exacerbating the severity of HIE and increasing mortality rates(19). A study from Nigeria highlighted that appropriate training in neonatal resuscitation can reduce neonatal mortality, thereby considerably reducing under-five mortality trends, especially in resourcepoor countries(20). This underscores the importance of not only equipment availability but also the training of healthcare providers in neonatal resuscitation techniques.

The study also revealed a high incidence of sepsis among neonates with HIE, which further complicates management and adversely affects outcomes. Implementing stringent infection control protocols, including hand hygiene, use of protective gear, and effective cleaning of surfaces and instruments, is essential to reduce infection risks(21). Additionally, practical measures such as antibiotic stewardship and the establishment of isolation areas in the NICU can protect these patients from severe infections.

The lack of advanced interventional procedures and equipment, such as TH and mechanical ventilation, in Atbara Teaching Hospital reflects a broader issue faced by many hospitals in developing countries(22). A survey on the diagnosis and management of neonatal hypoxicischemic encephalopathy in sub-Saharan Africa found that therapeutic hypothermia was available in only 13 countries, most frequently in private institutions(23). This disparity highlights the need for the equitable distribution of resources to manage HIE effectively across different healthcare settings. In conclusion, the management of HIE in Atbara Teaching Hospital is hindered by significant resource limitations, including the unavailability of therapeutic hypothermia and mechanical ventilation, as well as inadequate infection control measures. Addressing these challenges requires concerted efforts to improve healthcare infrastructure, train medical personnel, and implement standardized care protocols to enhance neonatal outcomes. Further studies are needed to evaluate the long-term outcomes of HIE survivors to develop appropriate interventions and improve neonatal care systems, thereby increasing survival and neurological outcomes.

5. Conclusion

This study underscores that hypoxic-ischemic encephalopathy (HIE) remains a significant contributor to neonatal mortality and neurological morbidity at Atbara Teaching Hospital's Neonatal Intensive Care Unit (NICU). The observed high mortality rate of 38.2%, extended NICU stays exceeding 10 days in nearly half of the cases, a sepsis incidence of 77.9%, and low Apgar scores in 56.5% of neonates highlight substantial deficiencies in current neonatal care practices.

A critical factor contributing to these adverse outcomes is the limited availability of essential interventions, notably therapeutic hypothermia and mechanical ventilation. Only 36.8% of neonates received mechanical ventilation, and therapeutic hypothermia was not administered, reflecting gaps in both equipment and clinical protocols. These findings align with existing literature emphasizing the efficacy of therapeutic hypothermia in reducing mortality and improving neurodevelopmental outcomes in neonates with moderate to severe HIE(24).

To address these challenges, it is imperative to invest in critical care resources, including the procurement and maintenance of ventilators and hypothermia equipment. Equally important is the enhancement of healthcare provider training in neonatal resuscitation, ventilatory support, and neuroprotective strategies. Implementing robust infection prevention and control protocols is also essential, given the high incidence of sepsis observed.

Furthermore, improving the physical infrastructure of the NICU to prevent overcrowding and facilitate optimal care delivery is recommended. Future research should focus on longitudinal studies to assess the long-term neurodevelopmental outcomes of HIE survivors, which will inform the development of targeted interventions and policies aimed at improving neonatal care systems in resource-limited settings.

6. Recommendations

To improve HIE outcomes, it is essential to equip NICUs with advanced monitoring and therapeutic devices, such as blood gas analysers and hypothermia systems. Future efforts should also consider incorporating structured follow-up programs and enhancing staff training based on the clinical burden identified.

Strengthen Early Identification and Resuscitation Protocols and Enhance Neonatal Resuscitation Training.

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