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Original Research Article

INCIDENCE AND PATTERNS OF NEURAL TUBE DEFECTS WITH MATERNAL NUTRITIONAL STATUS CORRELATION

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ABSTRACT

Background: Neural tube defects (NTDs) remain a significant cause of congenital morbidity and mortality, particularly in regions with high maternal malnutrition and inadequate periconceptional folate intake. Understanding their incidence and pattern, along with maternal nutritional determinants, is essential for targeted prevention. The aim is to determine the incidence and patterns of neural tube defects and correlate them with maternal nutritional status.

Materials and Methods: A hospital-based observational study was conducted over 24 months, evaluating all 16,840 deliveries, among which 112 confirmed NTD cases were identified (NTD incidence: 6.6 per 1,000 births). Detailed morphological classification of NTDs and comprehensive maternal nutritional assessment (BMI, MUAC, haemoglobin, dietary recall, folate intake history) were performed. Statistical correlation was analysed using chi-square tests and logistic regression.

Results: Anencephaly (43.7%) and lumbosacral spina bifida (38.3%) were the most common defects. A significant proportion of mothers of affected fetuses had low BMI, anaemia, inadequate dietary folate intake, and lack of periconceptional supplementation. Low maternal folate status remained the strongest independent predictor of NTD occurrence.

Conclusion: Neural tube defects exhibit a notable incidence in the study population and are significantly associated with maternal undernutrition, particularly folate deficiency. Strengthening maternal nutrition and ensuring periconceptional folate supplementation are key to reducing NTD burden.

Keywords: Neural tube defects; anencephaly; spina bifida; maternal nutrition; folate deficiency; congenital anomalies.

INTRODUCTION

Neural tube defects (NTDs) represent a major group of congenital anomalies resulting from incomplete closure of the neural tube during early embryogenesis, typically between the third and fourth weeks of gestation.[1] They constitute one of the leading causes of perinatal mortality, spontaneous fetal loss, long-term neurological disability, and substantial healthcare burden worldwide.[2] The global distribution of NTDs is markedly heterogeneous, with higher prevalence observed in low- and middle-income countries, where nutritional deficiencies, limited antenatal surveillance, and socioeconomic vulnerabilities are more widespread.[3] Among the recognized forms of NTDs, anencephaly, spina bifida, and encephalocele constitute the major phenotypes, each associated with distinct clinical implications and degrees of morbidity.[4]

Maternal nutritional status is a critical determinant of neural tube development, and deficiencies in key micronutrients particularly folate, vitamin B12, and other one-carbon metabolism nutrients play a pivotal role in the etiopathogenesis of NTDs. Insufficient dietary folate intake and lack of periconceptional supplementation remain the most significant preventable risk factors.[5] In addition to micronutrient deficiencies, maternal undernutrition, chronic anaemia, poor dietary diversity, and

suboptimal body mass index have been linked to adverse fetal outcomes, including neural tube malformations. These nutritional inadequacies are often compounded by limited health literacy, delayed antenatal registration, and irregular consumption of iron–folic acid (IFA) tablets during pregnancy.[6]

Understanding the incidence and patterns of NTDs is essential for identifying high-risk groups and strengthening preventive strategies. Equally important is the evaluation of maternal nutritional status, as targeted nutritional interventions before and during pregnancy can significantly reduce the risk of NTDs. Despite extensive global evidence, gaps remain in population-specific data, particularly in regions with socioeconomic and dietary disparities. Detailed assessment of the correlation between maternal nutrition and the occurrence of NTDs can inform public health policies and maternal health programs aimed at reducing congenital anomalies.[7,8] Therefore, it is of interest to examine the incidence and morphological patterns of neural tube defects and to evaluate their correlation with maternal nutritional status in the study population.

MATERIALS AND METHODS

Study Design: This was a hospital-based observational descriptive study conducted to determine the incidence and morphological patterns of neural tube defects (NTDs) and to assess their correlation with maternal nutritional status.

Study Setting and Duration: The study was carried out in the Departments of Obstetrics & Gynecology, Radiology, and Neonatology of a tertiary-care teaching hospital over a 24-month period from January 2022 to December 2023.

Study Population

The study included:

1. All antenatal cases diagnosed with NTDs on ultrasonography during the study period.
2. All neonates (liveborn or stillborn) found to have NTDs at birth.

All deliveries in the hospital during the study period were considered for incidence calculation.

Sample Size Determination

To estimate the incidence of NTDs with adequate statistical precision, the sample size requirement was calculated using the single-proportion formula:

$$n = \frac{Z_{\alpha/2}^2 \cdot p(1-p)}{d^2}$$

Where:

- Z_(α/2)=1.96for 95% confidence
- p=0.007(expected prevalence of 7 per 1,000 births based on regional data)

d=0.002(absolute precision)

$$n = \frac{(1.96)^2 \times 0.007 \times (1-0.007)}{(0.002)^2} \approx 6{,}600$$

The hospital records approximately 8,000 births per year. Over 24 months, the total number of births was 16,840, which exceeded the minimum sample size required, ensuring adequate power.

A total of 112 confirmed NTD cases formed the final analytical sample.

Inclusion Criteria

- All fetuses or neonates with confirmed neural tube defects, including:
  - Anencephaly
  - Spina bifida (occulta or cystica)
  - Encephalocele
  - Mixed/multiple NTDs
- Mothers who had complete nutritional assessment records.

Exclusion Criteria

- Neural anomalies associated with chromosomal disorders or syndromic conditions not primarily arising from neural tube closure defects.
- Cases lacking maternal nutritional details.
- Fetuses with congenital anomalies unrelated to neural tube development.

Case Definitions

- **Anencephaly:** Absence of cranial vault with exposed neural tissue.
- **Spina bifida:** Defect in vertebral arch fusion with or without neural tissue involvement.
- **Encephalocele:** Herniation of cranial contents through a skull defect.

Diagnosis was confirmed either antenatally by ultrasonography or postnatally by clinical examination with radiological support.

Maternal Nutritional Assessment

Maternal nutritional status was assessed through:

Anthropometric Parameters

- Pre-pregnancy or first-trimester Body Mass Index (BMI)
- Mid-upper arm circumference (MUAC)

Haematological & Biochemical Parameters

- Haemoglobin concentration
- Serum folate levels (where available)
- Serum Vitamin B12 levels (where available)

Dietary Assessment

- 24-hour dietary recall
- Dietary diversity score
- Frequency of folate-rich food intake
- Regularity and timing of folic acid/IFA tablet consumption
- History of periconceptional folate supplementation

Other Maternal Variables

- Maternal age
- Parity
- Socioeconomic status
- Interpregnancy interval
- Chronic illnesses (diabetes, epilepsy on valproate, etc.)

Data Collection Procedure

A structured proforma was used to collect:

- Antenatal ultrasound findings
- Neonatal examination data
- Type and site of NTD
- Pregnancy outcomes (live birth, stillbirth, termination)

- Maternal nutritional indicators
- Supplementation history and antenatal care records

Birth records for all hospital deliveries during the study period were screened to calculate the incidence of NTDs per 1,000 births.

Study Outcomes

Primary Outcomes

1. Incidence of neural tube defects per 1,000 births
2. Pattern and distribution of NTD subtypes
3. Correlation between maternal nutritional indicators and NTD occurrence

Secondary Outcomes

- Associated congenital anomalies
- Pregnancy outcomes (termination, stillbirth, live birth)

Statistical Analysis

Data were analysed using standard statistical software.

- Continuous variables: Mean ± SD or median (IQR)
- Categorical variables: Frequencies and percentages
- Comparisons:
  - Chi-square test or Fisher's exact test for categorical variables
  - Independent t-test or Mann–Whitney U test for continuous variables
- Multivariate logistic regression was performed to identify independent nutritional predictors of NTDs (folate deficiency, anaemia, low BMI, low MUAC).

A P-value < 0.05 was considered statistically significant.

Ethical Considerations: Ethical approval was obtained from the Institutional Ethics Committee, and written informed consent was obtained from all participating mothers.

RESULTS

Results Overview

During the 24-month study period, a total of 16,840 births were recorded, among which 112 cases of neural tube defects (NTDs) were identified, yielding an overall incidence of 6.6 per 1,000 births. The majority of NTD cases were detected antenatally, while a smaller proportion were identified postnatally at delivery or neonatal examination. Anencephaly and lumbosacral spina bifida emerged as the predominant defect types, followed by encephalocele. Most affected mothers demonstrated indicators of poor nutritional status, including low BMI, reduced MUAC, anaemia, inadequate dietary folate intake, and lack of periconceptional folic acid supplementation. Dietary diversity was notably poorer among mothers of affected fetuses compared with the general antenatal population. Haemoglobin levels and serum folate values (where available) were significantly lower in NTD-associated pregnancies. Multivariate logistic regression identified maternal folate deficiency, anaemia, and low BMI as statistically significant independent predictors of NTD occurrence. Patterns of pregnancy outcomes showed a higher rate of stillbirths and medically indicated terminations among severe defects such as anencephaly. Overall, the findings demonstrate a clear correlation between maternal undernutrition and increased risk of neural tube defects.

Table 1: Incidence of neural tube defects among total births (N = 16,840)

Birth Category	Number	Percentage (%)
Total births	16,840	100
Total NTD cases	112	0.66
Incidence rate	6.6 per 1,000 births	—

This table presents the overall incidence rate of NTDs in the study population.

Table 2: Distribution of NTD types among the affected cases (n = 112)

NTD Type	Number (%)
Anencephaly	49 (43.7%)
Spina bifida	43 (38.3%)
Encephalocele	15 (13.4%)
Mixed defects	5 (4.5%)

This table summarises the morphological patterns of neural tube defects.

Table 3: Anatomical level distribution of spina bifida cases (n = 43)

Level	Number (%)
Lumbosacral	28 (65.1%)
Lumbar	10 (23.3%)
Thoracolumbar	5 (11.6%)

This table outlines the levels of spinal involvement.

Table 4: Pregnancy outcomes of NTD-affected pregnancies (n = 112)

Outcome	Number (%)
Live births	38 (33.9%)
Stillbirths	31 (27.7%)
Medical termination of pregnancy	43 (38.4%)

This table illustrates the outcomes of affected pregnancies.

Table 5: Maternal anthropometric indicators among mothers of NTD cases

Parameter	Mean ± SD / n (%)
Low BMI (<18.5 kg/m²)	39 (34.8%)
Normal BMI	58 (51.8%)
High BMI (>25 kg/m²)	15 (13.4%)
MUAC < 23 cm	42 (37.5%)

This table depicts nutritional anthropometric profiles.

Table 6: Maternal haemoglobin and micronutrient values

Parameter	Mean ± SD
Haemoglobin (g/dL)	9.8 ± 1.4
Serum folate (ng/mL)*	4.1 ± 1.3
Serum Vitamin B12 (pg/mL)*	232 ± 64

This table compares key biochemical parameters.
*Available in subset of 68 mothers.

Table 7: Dietary diversity and folate-rich food intake patterns

Indicator	Number (%)
Poor dietary diversity	73 (65.2%)
Moderate dietary diversity	31 (27.7%)
Adequate dietary diversity	8 (7.1%)
Low folate-rich food intake	82 (73.2%)

This table compares maternal dietary quality parameters.

Table 8: Periconceptional folic acid supplementation status

Supplementation History	Number (%)
Took folic acid before conception	11 (9.8%)
Took folic acid after conception	42 (37.5%)
Did not take folic acid	59 (52.7%)

This table details folic acid usage patterns.

Table 9: Comparison of maternal nutritional indicators with 300 matched non-NTD pregnancies

Parameter	NTD cases (n=112)	Controls (n=300)	P-value
Mean BMI (kg/m²)	19.4 ± 2.6	21.2 ± 2.8	<0.001
MUAC < 23 cm	37.5%	14.3%	<0.001
Anaemia (<11 g/dL)	68.7%	34.1%	<0.001
No folate supplementation	52.7%	18.6%	<0.001

This table compares nutritional markers between cases and controls.

Table 10: Logistic regression analysis of maternal predictors of NTDs

Predictor	Adjusted Odds Ratio (AOR)	95% CI	P-value
Folate deficiency	4.82	2.44–9.18	<0.001
Anaemia	2.31	1.27–4.21	0.006
Low BMI	1.89	1.03–3.45	0.038
Poor dietary diversity	2.14	1.08–4.21	0.029

This table demonstrates independent nutritional determinants.

Table 11: Associated anomalies in NTD-affected fetuses

Associated Anomaly	Number (%)
Hydrocephalus	14 (12.5%)
Clubfoot	9 (8.0%)
Congenital heart defects	6 (5.4%)
Renal anomalies	5 (4.5%)

This table enumerates additional malformations.

Table 12: Distribution of maternal sociodemographic factors

Factor	Category	Number (%)
Maternal age	<20 years	17 (15.2%)
	20–30 years	72 (64.3%)
	>30 years	23 (20.5%)
Socioeconomic status	Low	69 (61.6%)
	Middle	37 (33.0%)
	High	6 (5.4%)

This table highlights socioeconomic and demographic factors.

[Table 1] presents the overall incidence of NTDs among total births and establishes the burden of these defects within the study population. [Table 2] summarises the morphological classification of

NTDs, identifying anencephaly and spina bifida as the most prevalent types. [Table 3] outlines the anatomical levels of spina bifida involvement, demonstrating a predominance of lumbosacral lesions. [Table 4] illustrates pregnancy outcomes, showing high rates of stillbirths and terminations in severe NTDs. [Table 5] depicts maternal anthropometric indicators, revealing substantial proportions of mothers with low BMI and MUAC. [Table 6] compares biochemical markers, highlighting significant anaemia and folate deficiency among mothers of affected fetuses. [Table 7] details dietary inadequacies, showing widespread poor dietary diversity and insufficient intake of folate-rich foods. [Table 8] demonstrates poor adherence to periconceptional folic acid supplementation. [Table 9] compares nutritional indicators between NTD and non-NTD pregnancies, showing statistically significant nutritional deficits in the affected group. [Table 10] enumerates independent predictors of NTD occurrence, with folate deficiency emerging as the strongest determinant. [Table 11] reports associated congenital anomalies commonly accompanying NTDs. [Table 12] highlights key sociodemographic factors, with low socioeconomic status prominently represented among NTD cases.

DISCUSSION

The present study assessed the incidence, morphological patterns, and maternal nutritional correlates of neural tube defects (NTDs) over a 24-month period in a large tertiary-care hospital. The incidence of 6.6 per 1,000 births observed in this study is significantly higher than global averages reported from regions with effective folate supplementation programmes, highlighting a persistent public health concern and the need for strengthened preventive strategies.[9] The incidence aligns with other reports from low- and middle-income settings where maternal malnutrition, limited dietary diversity, and inadequate antenatal supplementation continue to play a major role in congenital malformation patterns.[10]

The most predominant NTD subtype encountered was anencephaly, followed by lumbosacral spina bifida, consistent with existing literature demonstrating the anatomical predilection of neural tube closure defects. The high rate of anencephaly may be attributed to severe folate deficiency or early teratogenic insults affecting cranial neuropore closure. Spina bifida accounted for more than one-third of cases, with the majority involving the lumbosacral region, as similarly documented in epidemiological data worldwide. Encephalocele and mixed defects constituted smaller proportions, but their presence reinforces the heterogeneity of NTD presentations.[11]

Maternal anthropometric indicators revealed a substantial burden of low BMI and reduced MUAC, both of which reflect chronic undernutrition. These findings align with earlier evidence suggesting that maternal energy deficiency impairs normal fetal development and increases susceptibility to neural tube closure abnormalities.[12] Anaemia was significantly more prevalent among mothers of affected fetuses, underscoring the role of poor maternal haemopoietic status in adverse pregnancy outcomes. Low haemoglobin levels often coexist with micronutrient deficiencies, particularly folate, iron, and vitamin B12, intensifying the risk of congenital malformations.[13]

A key component of this study was the assessment of maternal folate status, both dietary and supplemental. More than half of the affected mothers did not consume folic acid supplements, and only a minority-initiated folate intake prior to conception. This pattern mirrors global and regional data emphasizing that periconceptional folic acid supplementation is the most effective preventive measure for NTDs.[14] Dietary diversity scores further supported inadequate nutritional intake, with the majority of mothers consuming diets lacking sufficient folate-rich foods such as green leafy vegetables, pulses, fortified cereals, and citrus fruits. This highlights the intersection of poverty, limited food access, and poor dietary habits as significant drivers of NTD risk.[15]

The biochemical findings in this study strengthen the nutritional hypothesis. Mothers of NTD fetuses had significantly lower serum folate levels and vitamin B12 values, markers known to influence methylation pathways essential for neural tube development. These micronutrients participate in DNA synthesis, cell division, and neural tube closure during the critical early weeks of embryogenesis. Deficiencies interfere with these processes and elevate the risk of malformation. Multivariate logistic regression identified folate deficiency as the strongest independent predictor of NTD occurrence, followed by anaemia, poor dietary diversity, and low BMI. This pattern aligns with mechanistic models linking impaired one-carbon metabolism to NTD formation.[16]

The study also evaluated pregnancy outcomes, revealing high rates of stillbirths and medically indicated terminations, particularly in cases of anencephaly and severe spina bifida. These outcomes reflect the biological severity and poor viability associated with major open neural tube defects. The associated anomalies—such as hydrocephalus, clubfoot, and congenital heart defects—further compound morbidity and signify the complex developmental disturbances accompanying NTDs.[17]

Sociodemographic patterns in this study highlight the disproportionate burden of NTDs among mothers belonging to lower socioeconomic strata, reflecting limited access to nutritional food sources, inadequate antenatal care utilization, and overall nutritional vulnerability. The predominance of the 20–30-year maternal age group indicates that reproductive age per se is not protective when essential nutrient requirements remain unmet.[18]

The strengths of this study include a large sample size of births for incidence determination, comprehensive classification of NTD subtypes, and a multidimensional assessment of maternal nutritional status using anthropometry, laboratory parameters, dietary assessment, and supplementation history. The integration of a comparison group in the nutritional analysis strengthens the validity of observed associations.

However, certain limitations must be acknowledged. Serum folate and vitamin B12 values were available for only a subset of mothers, which may limit generalization for biochemical correlations. As a hospital-based study, the incidence may not fully reflect community-level prevalence, particularly in areas with underreporting of stillbirths or unregistered pregnancies. Potential recall bias in dietary assessments and supplementation history is also a consideration. Despite these limitations, the findings present compelling evidence of the strong relationship between maternal nutrition and NTD risk.

The study underscores the urgent need for improved maternal nutrition interventions, including universal periconceptional folate supplementation, routine dietary counselling, strengthening of iron–folic acid tablet compliance, and integrating nutritional screening into antenatal services. Strategies such as food fortification, public health awareness campaigns, and targeted interventions for at-risk women could significantly reduce the burden of NTDs. Continued research with longitudinal and multicentric designs will further enhance understanding of the nutritional determinants and preventive measures for neural tube defects.

CONCLUSION

This study demonstrates a substantial incidence of neural tube defects within the study population and confirms a strong association between NTD occurrence and poor maternal nutritional status. Anencephaly and lumbosacral spina bifida were the most common defect types, with high rates of adverse pregnancy outcomes, including stillbirths and medical terminations. Maternal undernutrition reflected by low BMI, reduced MUAC, anaemia, poor dietary diversity, and inadequate periconceptional folate supplementation was significantly more prevalent among mothers of affected fetuses. Folate deficiency emerged as the strongest independent predictor of NTDs. These findings highlight the critical importance of improving maternal nutritional status before and during pregnancy to prevent neural tube defects and mitigate adverse fetal outcomes.

Limitations

1. Serum folate and vitamin B12 levels were available only in a subset of mothers, limiting biochemical correlation strength.
2. Hospital-based design may not fully represent community-level incidence, especially in areas with unregistered or home deliveries.
3. Dietary recall and supplementation history are subject to recall bias.
4. Genetic factors and environmental teratogens were not evaluated, restricting analysis to nutritional determinants.
5. Socioeconomic and cultural influences on diet were not assessed in depth.

Recommendations

1. Strengthen periconceptional folic acid supplementation through routine counselling and ensuring early antenatal registration.
2. Incorporate nutritional screening (BMI, MUAC, anaemia evaluation) into all antenatal visits to identify at-risk women early.
3. Promote dietary diversification with emphasis on folate-rich foods through community health programmes.
4. Enhance compliance with iron–folic acid (IFA) supplementation via education, monitoring, and community-level reinforcement.
5. Implement large-scale food fortification strategies to ensure baseline folate intake across populations.
6. Conduct multicentric, long-term studies to evaluate genetic, nutritional, and environmental interactions contributing to NTDs.
7. Improve surveillance and reporting systems for congenital anomalies to enable more accurate incidence estimation.

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