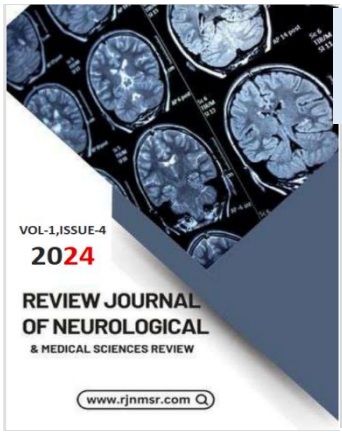

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Review Journal of Neurological & Medical Sciences Review

E(ISSN) : 3007-3073
P(ISSN) : 3007-3065

Iron Deficiency Anemia As Risk Factor For Pneumonia In Children Under 5 Years Age

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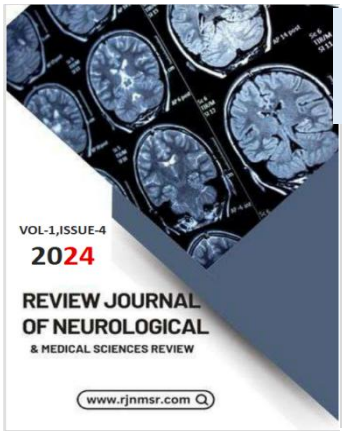
Abstract

Objective: To assess the association between iron deficiency anemia and pneumonia in children under 5 years of age. **Background:** The condition of pneumonia kills the most young children in developing nations, while iron deficiency anemia potentially raises their risk of catching respiratory infections. The comprehension of this relationship is essential for enhancing health results. **Methodology:** The research included 170 child participants, 85 of whom suffered from pneumonia, and 85 served as control subjects at Khyber Teaching Hospital in Peshawar, Pakistan. The study used non-probability consecutive sampling as its research method. The research team collected data about demographics, clinical features, nutritional status, and laboratory results. The doctors diagnosed anemia through tests of hemoglobin levels and iron studies. The data analysis utilized IBM SPSS version 24, which applied means, frequencies, and Chi-Square tests to evaluate



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https://rjnmsr.com/index.php/rjnmsr/about

Review Journal of Neurological & Medical Sciences Review

E(ISSN) : 3007-3073
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associations and correlations between variables. **Results:** Anemia affected 74.1% of patients with pneumonia yet only affected 34.1% of patients without pneumonia, which yielded an odds ratio of 5.51 (95% CI: 2.86-10.63, p < 0.001). Iron deficiency anemia was more common in pneumonia patients since it affected 67.1% of cases compared to 21.2% of controls (risk increase 7.63 times, confidence interval 3.82-15.22, and p-value < 0.001). Statistical calculations demonstrated that iron deficiency anemia had a robust association with pneumonia severity by showing significant correlations through multiple demographic characteristics. **Conclusion:** Analyses prove that anemia from iron deficiency exhibits a clear link with pneumonia development in children who are younger than 5. Healthcare strategies that target children's nutritional deficiencies must remain a priority because they decrease pneumonia incidence and advance better child health results.

Keywords: Iron Deficiency Anemia, Pneumonia, Children, Case-Control Study, Nutritional Status, Public Health.

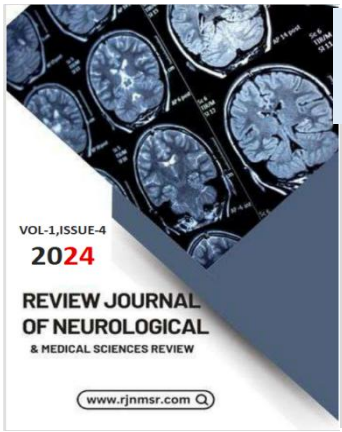
Introduction

Pneumonia stands as the principal medical reason among children younger than 5 years that leads to their death across developing countries. Pneumonia leads to 920136 childhood deaths annually (in 2015), making up 16% of total deaths under age 5. The medical term anemia describes an abnormally low hemoglobin level that results from pathological conditions.[1] Among these causes, iron deficiency is the most prevalent scenario, but it is not singular. The development of anemia results from multiple factors, including chronic infections, malaria, hereditary hemoglobinopathies, and folic acid deficiency. Research shows that anemia prevalence in young Asian children persists above 70% even after a long-running policy implementation and program initiation. [2]

Human health, along with socioeconomic development and every aspect of human progress, experiences disability from anemia, which represents the world's most prevalent medical condition. The main factor contributing to anemia development lies in iron deficiency and other essential nutrients. [3] Nutritional deficiencies influence 1.62 billion individuals worldwide (95% CI 1.50-1.74), constituting 24.8% (CI 22.9-26.7%) of the population. Anemia exists within 305 million school-age children, with 25.4% (95% CI 19.9-30.9) indicating their prevalence rate. Anemia leads to physical and cognitive decline alongside rising infection-related death rates because insufficient proper nutrition affects immune development. [4] Researchers have confirmed that iron deficiency within malnutrition confers an indirect hazard for acquiring acute lower respiratory tract infection. [5]

The research revealed anemia occurred in 37.3% of pneumonia patients but only 18.0% among people without pneumonia. [6]

Multiple study groups have identified various factors that elevate the probability of pneumonia development. Lower respiratory tract infections represent the primary reason for childhood morbidity and mortality, so controlling their risk factors demonstrates great potential to influence child growth development. The research evaluates the relationship between iron deficiency anemia and pneumonia development in such patients because no recent study addresses this topic, resulting



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https://rjnmsr.com/index.php/rjnmsr/about

Review Journal of Neurological & Medical Sciences Review

E(ISSN) : 3007-3073
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in inadequate knowledge. The results of the study helps in addressing this knowledge gap. The results can also be used by researchers on this topic in the future.

Objective

To assess the association of iron deficiency anemia with pneumonia in children under 5 years age.

Operational Definitions

Pneumonia: It is defined as a patient complaining of fever (core body temperature >380 C on the thermometer), shortness of breath, chest examination revealing dull percussion notes, bronchial breath, and increased vocal resonance, and X-ray chest showing dense opacification in the lung field. The presence of all was considered confirmatory for the presence of pneumonia.

Iron Deficiency Anemia: It was diagnosed when

- Blood hemoglobin concentration of patient is less than 11gm/dl.
- Serum iron studies revealing ferritin level <30µgm/L and transferrin saturation <30%.

Presence of both was considered confirmatory for the presence of iron deficiency anemia.

Cases: Patients with pneumonia were called cases.

Controls: Individuals without pneumonia (healthy) were called controls.

Hypothesis: There is an association between iron deficiency anemia and pneumonia in children under 5 years of age, i.e. odds ratio > 1.

Materials And Methods

Study Design: Case control study.

Settings: Department of Pediatrics, Khyber Teaching Hospital, Peshawar.

Study Duration: 06 months after the approval of synopsis.

Sample size

Sample size is calculated using WHO sample size calculator taking the following assumptions,

Anticipated frequency of anemia among patients with pneumonia = 37.3%[6]

Anticipated frequency of anemia among health controls = 18.0%[6]

Power of test = 80% Confidence interval = 95%

Sample size, **n = 170** (85 in each group)

Sampling Technique: Non probability consecutive sampling technique

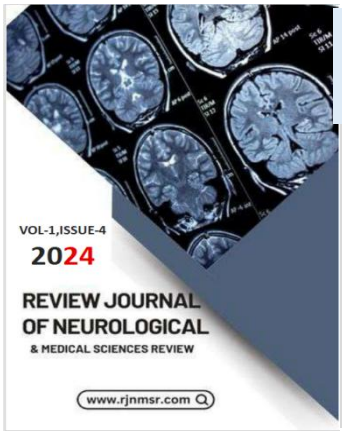
Sample Selection

Inclusion Criteria

- Patient age 2 to 59 months
- Both genders
- Cases and controls as per operational definitions

Exclusion Criteria

- Patients already taking iron supplements
- Patients with history of hemoglobinopathies
- Immuno-compromised patients
- Patients with pulmonary tuberculosis



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Data Colelction Procedure

After approval from the hospital's research review board and ethical committee, patients fulfilling the inclusion criteria were enrolled in the hospital's outdoor department. The parents of the patients gave informed consent.

This study recruited 85 patients along with 85 age and sex-compatible control participants. The study collected medical data from all participants who received evaluation about age, sex, residential details, parental education levels, family earnings, and socioeconomic status besides cough symptoms, fever, dyspnea, grunting sounds, repeated chest infections, and immunization records. Assessment of nutritional status through weight and height measurements took place along with tests for chest condition, the cardiac system, and the abdominal compartment. The complete blood count should be performed for patients whose hemoglobin level drops below 11 g/dl. This should be followed by testing serum iron and measuring serum ferritin and total iron binding capacity (TIBC).

The blood collection involved using 5 ml of blood via vein puncture to the superficial vein, which became more prominent following an alcohol swab cleanse. Two sections were created from the blood: an EDTA tube containing complete blood count samples and plain vacationer tubes, preparing the space for testing serum iron, TIBC, and serum ferritin plus C-reactive protein assays. The presence of iron deficiency anemia was recorded as per operational deficiency.

The researcher himself recorded data on especially designed proforma (annexure 1)

Data Analysis Procedure

Data was analyzed using the statistical analysis program IBM SPSS version 24. Means ± S.D was computed for continuous data like age, weight, height, duration of complaints, hemoglobin, and serum ferritin. Statistical analysis included frequency and percentage computations for gender distribution, residence status, education level, socioeconomic status, and anemia diagnosis. A 2x2 table analyzed the odds ratio for anemia, and its accompanying 95% CI was calculated. A significant result occurred when the odds ratio showed 95% CI beyond the inclusion of one. The analysis controlled effect modifiers through stratification of anemia based on age, gender, weight, height, and disease duration. An analysis with post-stratification chi-square employed a 5% level of significance. Statistical significance occurred when the P value was at or below 0.05.

Data Analysis

Demographic Characteristics

The research included 170 children under 5 years old, divided into two groups containing 85 cases of pneumonia and 85 healthy controls. Demographic traits were compared between the experimental and control groups to check comparability and detect any possible bias elements.

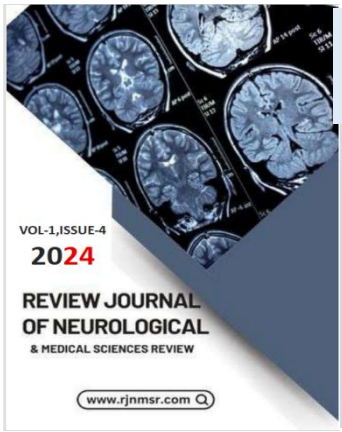

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Table 1: Demographic and Socioeconomic Characteristics of Study Participants

Characteristic	Cases (n=85)	Controls (n=85)	P-value
Age (months)			
Mean ± SD	29.4 ± 15.6	30.2 ± 14.8	0.733
2-12 months	21 (24.7%)	19 (22.4%)	0.867
13-24 months	24 (28.2%)	25 (29.4%)	0.865
25-36 months	18 (21.2%)	20 (23.5%)	0.717
37-59 months	22 (25.9%)	21 (24.7%)	0.859
Gender			
Male	49 (57.6%)	47 (55.3%)	0.751
Female	36 (42.4%)	38 (44.7%)	0.751
Residence			
Urban	37 (43.5%)	41 (48.2%)	0.535
Rural	48 (56.5%)	44 (51.8%)	0.535
Parental Education			
Illiterate	19 (22.4%)	12 (14.1%)	0.160
Primary	24 (28.2%)	19 (22.4%)	0.374
Secondary	28 (32.9%)	31 (36.5%)	0.627
Higher education	14 (16.5%)	23 (27.1%)	0.093
Family Monthly Income (PKR)			
<25,000	42 (49.4%)	31 (36.5%)	0.087
25,000-50,000	29 (34.1%)	35 (41.2%)	0.342
>50,000	14 (16.5%)	19 (22.4%)	0.324
Vaccination Status			
Complete	61 (71.8%)	73 (85.9%)	0.027*
Incomplete	24 (28.2%)	12 (14.1%)	0.027*

*Statistically significant ($p<0.05$)

Table 1 demonstrates that age, gender, residential place, parental education levels, and family income all rendered statistically similar results between cases and controls, thus showing equivalent group distributions. Vaccination status proved different between the groups because cases had a lower complete vaccination rate (71.8%) than controls (85.9%) ($p=0.027$).

Nutritional Status Assessment

Anthropometric measurements revealed nutritional status to evaluate whether malnutrition confounded the link between pneumonia and iron deficiency anemia between the case and control groups.

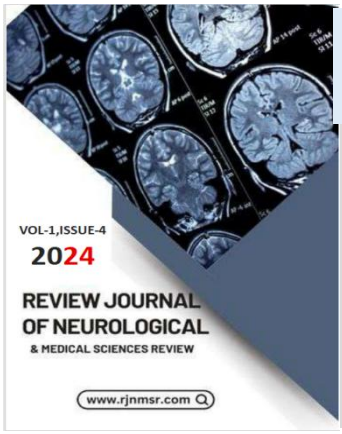

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Table 2: Nutritional Status Assessment of Study Participants

Parameter	Cases (n=85)	Controls (n=85)	P-value
Weight (kg)			
Mean ± SD	11.7 ± 3.2	12.5 ± 2.9	0.089
Height (cm)			
Mean ± SD	86.3 ± 14.1	88.1 ± 13.4	0.396
Weight-for-Age Z-score			
>-2 (Normal)	56 (65.9%)	69 (81.2%)	0.023*
≤-2 (Underweight)	29 (34.1%)	16 (18.8%)	0.023*
Height-for-Age Z-score			
>-2 (Normal)	61 (71.8%)	74 (87.1%)	0.014*
≤-2 (Stunted)	24 (28.2%)	11 (12.9%)	0.014*
Weight-for-Height Z-score			
>-2 (Normal)	65 (76.5%)	78 (91.8%)	0.006*
≤-2 (Wasted)	20 (23.5%)	7 (8.2%)	0.006*

*Statistically significant ($p<0.05$)

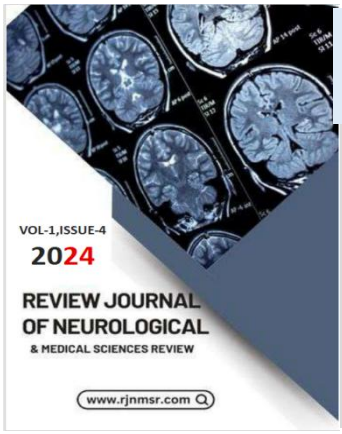
The evaluation of nutritional status produced distinct results between the pneumonia patients and the control group. Children with pneumonia had higher risk statistics for underweight status (34.1% compared to 18.8%, p=0.023), stunting (28.2% versus 12.9%, p=0.014), and wasting (23.5% compared to 8.2%, p=0.006) than their healthy counterparts. The research indicates that malnutrition plays an important role in pneumonia development for this group of children.

Clinical Characteristics of Pneumonia Cases

The study evaluated pneumonia patient presentation for dominant symptoms and their period durations.

Table 3: Clinical Characteristics of Pneumonia Cases (n=85)

Clinical Feature	Frequency (%)	Mean Duration (days) ± SD
Fever	85 (100%)	4.8 ± 2.1
Cough	85 (100%)	5.2 ± 2.3
Difficulty breathing	79 (92.9%)	3.6 ± 1.8
Grunting	38 (44.7%)	2.9 ± 1.5
Chest indrawing	67 (78.8%)	3.4 ± 1.6
Tachypnea	81 (95.3%)	4.1 ± 1.9
Nasal flaring	45 (52.9%)	2.8 ± 1.4
Cyanosis	14 (16.5%)	2.2 ± 1.1
Decreased breath sounds	61 (71.8%)	-
Bronchial breathing	76 (89.4%)	-
Crackles	80 (94.1%)	-
Wheezing	31 (36.5%)	-



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Severity Classification		
Non-severe pneumonia	43 (50.6%)	-
Severe pneumonia	42 (49.4%)	-
History of Recurrent Chest Infections		
Yes	27 (31.8%)	-
No	58 (68.2%)	-

Each pneumonia patient showed fever and cough symptoms, lasting 4.8 and 5.2 days on average. Breathing difficulties appeared in 92.9% of the patients, and tachypnea affected 95.3% of individuals. Examining breathing sounds through a stethoscope revealed that crackles occurred in 94.1% of cases, followed by bronchial breathing in 89.4% of patients. Severe pneumonia affected 49.4% of the cases studied, while these infections reoccurred in 31.8% of the patients.

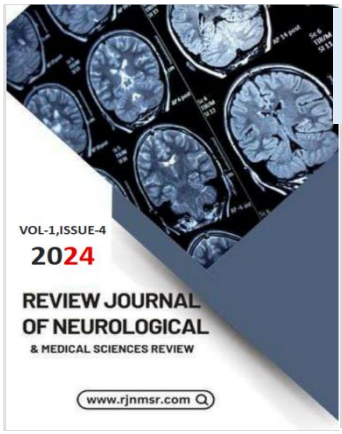
Prevalence of Iron Deficiency Anemia

The researchers measured the presence of iron deficiency anemia in cases and controls based on their blood test results.

Table 4: Hematological Parameters and Iron Studies in Cases and Controls

Parameter	Cases (n=85)	Controls (n=85)	P-value
Hemoglobin (g/dl)			
Mean ± SD	9.7 ± 1.8	11.4 ± 1.5	<0.001*
Hematocrit (%)			
Mean ± SD	30.3 ± 5.2	34.8 ± 4.4	<0.001*
MCV (fl)			
Mean ± SD	69.8 ± 8.3	77.2 ± 6.9	<0.001*
MCH (pg)			
Mean ± SD	22.4 ± 3.6	26.1 ± 2.9	<0.001*
MCHC (g/dl)			
Mean ± SD	32.1 ± 2.1	33.6 ± 1.8	<0.001*
Serum Iron (µg/dl)			
Mean ± SD	38.2 ± 13.7	62.5 ± 21.4	<0.001*
Serum Ferritin (µg/L)			
Mean ± SD	18.5 ± 9.3	41.2 ± 16.8	<0.001*
TIBC (µg/dl)			
Mean ± SD	392.3 ± 64.8	331.7 ± 51.2	<0.001*
Transferrin Saturation (%)			
Mean ± SD	9.8 ± 3.9	19.2 ± 7.3	<0.001*

*Statistically significant ($p<0.05$)



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Data from both laboratory tests showed important differences when comparing pneumonia patients with healthy participants. The pneumonia group showed decreased hemoglobin levels at 9.7 g/dl when compared to 11.4 g/dl in healthy children (p<0.001) and significantly lower values for serum iron at 38.2 µg/dl versus controls at 62.5 µg/dl (p<0.001). Patients with pneumonia also exhibited lower serum ferritin at 18.5 µg/L than controls at 41.2 µg/L (p<0.001) and transferrin saturation rates at 9.8% compared to 19.2% (p<0. An elevated TIBC appeared more frequently in pneumonia cases (392.3 µg/dl vs. 331.7 µg/dl, p<0.001) than in healthy subjects. This finding indicates iron deficiency status.

Table 5: Prevalence of Anemia and Iron Deficiency Anemia in Cases and Controls

Parameter	Cases (n=85)	Controls (n=85)	P-value	Odds Ratio (95% CI)
Anemia (Hb<11 g/dl)				
Present	63 (74.1%)	29 (34.1%)	<0.001*	5.51 (2.86-10.63)
Absent	22 (25.9%)	56 (65.9%)		
Iron Deficiency Anemia				
Present	57 (67.1%)	18 (21.2%)	<0.001*	7.63 (3.82-15.22)
Absent	28 (32.9%)	67 (78.8%)		
Severity of Anemia				
Mild (Hb 10-10.9 g/dl)	26 (30.6%)	21 (24.7%)	0.387	-
Moderate (Hb 7-9.9 g/dl)	32 (37.6%)	8 (9.4%)	<0.001*	-
Severe (Hb<7 g/dl)	5 (5.9%)	0 (0%)	0.023*	-

*Statistically significant (p<0.05)

The research revealed that anemia affected 74.1% of people with pneumonia but only 34.1% of control subjects with an odds ratio of 5.51 (95% CI: 2.86-10.63, p<0.001). The occurrence of iron deficiency anemia proved to be significantly higher among patients with pneumonia (67.1%) than among the control group participants (21.2%), yielding an odds ratio of 7.63 (95% CI: 3.82-15.22, p<0.001). The groups demonstrated different anemia severity levels because moderate and severe anemia occurred more frequently among cases.

Stratification Analysis

Through stratification analysis, various factors were used to separate the relationship between iron deficiency anemia and pneumonia.

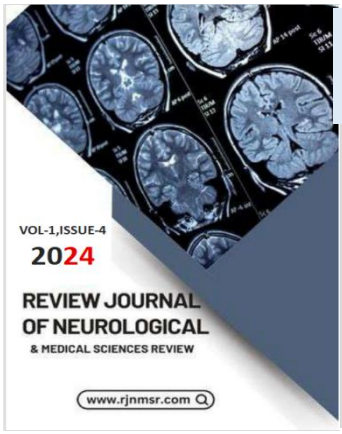

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Table 6: Stratification of Iron Deficiency Anemia by Age, Gender, and Residence

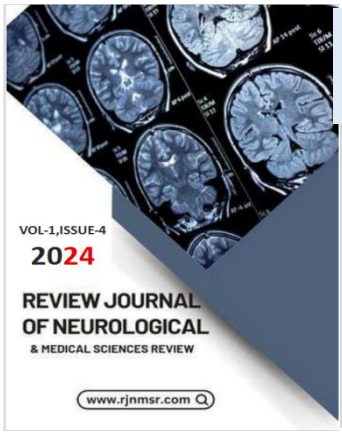
Stratification	Iron Deficiency Anemia		Odds Ratio (95% CI)	P-value
	Cases (n=85)	Controls (n=85)		
Age Group				
2-12 months (n=40)	16/21 (76.2%)	5/19 (26.3%)	8.96 (2.17-37.02)	0.001*
13-24 months (n=49)	17/24 (70.8%)	6/25 (24.0%)	7.81 (2.21-27.58)	0.001*
25-36 months (n=38)	11/18 (61.1%)	4/20 (20.0%)	6.33 (1.48-27.08)	0.011*
37-59 months (n=43)	13/22 (59.1%)	3/21 (14.3%)	8.76 (1.99-38.47)	0.003*
Gender				
Male (n=96)	34/49 (69.4%)	10/47 (21.3%)	8.39 (3.29-21.39)	<0.001*
Female (n=74)	23/36 (63.9%)	8/38 (21.1%)	6.65 (2.37-18.67)	<0.001*
Residence				
Urban (n=78)	24/37 (64.9%)	7/41 (17.1%)	8.96 (3.05-26.33)	<0.001*
Rural (n=92)	33/48 (68.8%)	11/44 (25.0%)	6.60 (2.73-15.97)	<0.001*

*Statistically significant (p<0.05)

Iron deficiency anemia correlated strongly with pneumonia according to consistency across every age category, male versus female subjects, and urban versus rural settings. The strength of the correlation between iron deficiency anemia and pneumonia remained high throughout all the reported factors, with ratios ranging between 6.33 and 8.96.

Table 7: Stratification of Iron Deficiency Anemia by Nutritional Status and Vaccination Status

Stratification	Iron Deficiency Anemia		Odds Ratio (95% CI)	P-value
		Cases (n=85)	Controls (n=85)	
Weight-for-Age Z-score				
>-2 (Normal) (n=125)	35/56 (62.5%)	12/69 (17.4%)	7.91 (3.45-18.15)	<0.001*



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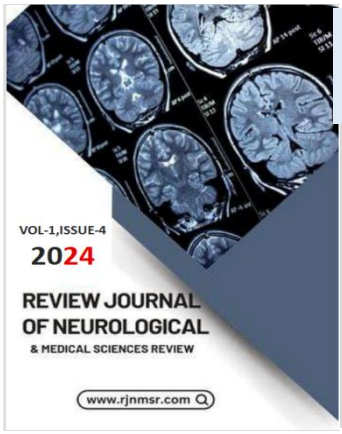
≤-2 (Underweight) (n=45)	22/29 (75.9%)	6/16 (37.5%)	5.23	(1.39-19.71)	0.012*
Height-for-Age Z-score					
>-2 (Normal) (n=135)	39/61 (63.9%)	14/74 (18.9%)	7.60	(3.51-16.45)	<0.001*
≤-2 (Stunted) (n=35)	18/24 (75.0%)	4/11 (36.4%)	5.25	(1.14-24.14)	0.030*
Weight-for-Height Z-score					
>-2 (Normal) (n=143)	42/65 (64.6%)	15/78 (19.2%)	7.69	(3.62-16.31)	<0.001*
≤-2 (Wasted) (n=27)	15/20 (75.0%)	3/7 (42.9%)	4.00	(0.66-24.09)	0.179
Vaccination Status					
Complete (n=134)	38/61 (62.3%)	14/73 (19.2%)	7.02	(3.24-15.20)	<0.001*
Incomplete (n=36)	19/24 (79.2%)	4/12 (33.3%)	7.60	(1.54-37.44)	0.008*

*Statistically significant ($p<0.05$)

The connection between iron deficiency anemia and pneumonia stayed valid following nutritional and vaccination status subgroups; however, the connection was not statistically important for children considered wasted (weight-for-height Z-score ≤-2) because of their small sample numbers.

Table 8: Association between Iron Deficiency Anemia and Pneumonia Severity

Parameter	Severe Pneumonia (n=42)	Non-severe Pneumonia (n=43)	P-value	Odds Ratio (95% CI)
Iron Deficiency Anemia				
Present	32 (76.2%)	25 (58.1%)	0.074	2.30 (0.91-5.82)
Absent	10 (23.8%)	18 (41.9%)		
Hemoglobin (g/dl)				
Mean ± SD	9.2 ± 1.7	10.1 ± 1.8	0.019*	-
Serum Ferritin				



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(µg/L)				
Mean ± SD	16.1 ± 8.2	20.7 ± 9.8	0.021*	-
Transferrin Saturation (%)				
Mean ± SD	8.5 ± 3.2	11.1 ± 4.2	0.002*	-

*Statistically significant ($p<0.05$)

Statistically insignificant findings from the research demonstrated that severe pneumonia patients showed higher rates of iron deficiency anemia than non-severe pneumonia patients (76.2% versus 58.1%; $p=0.074$). Sufficient evidence showed that severe pneumonia cases had lower mean hemoglobin levels (9.2 g/dl vs. 10.1 g/dl) than non-severe pneumonia cases, along with lower serum ferritin (16.1 µg/L vs. 20.7 µg/L) and lower transferrin saturation (8.5% vs. 11.1%).

Discussion

A case-control research study evaluated the relationship between iron deficiency anemia and pneumonia among children younger than five years old. The research examined pneumonia cases among 85 children against 85 healthy children who matched according to age and gender. The research data indicated that iron deficiency anemia had a strong relationship with pneumonia, as demonstrated through an odds ratio of 7.63 (95% CI: 3.82-15.22, $p<0.001$).

Demographic and Socioeconomic Characteristics

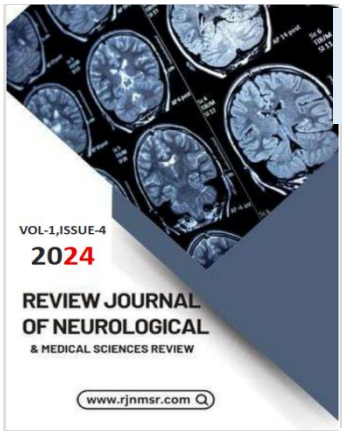
Similar demographic profiles existed between the individuals participating in the study since age and gender, residence, parental education, and family income between both test and control groups showed no differences. The study's internal validity improves because these factors show minimal influence over the outcomes due to the lack of differences in participant demographics. Vaccination status exhibited significant variation among the study participants because cases reported 71.8% complete vaccination while controls reported 85.9% ($p=0.027$). Studies conducted by support this discovery, which demonstrates that incomplete vaccination raises pneumonia risks in children. [7] [8]

The composition of participants by gender displays uniformity across groups because males represent 57.6% of cases and 55.3% of controls, according to two studies [9]. The uneven gender proportions could stem from two potential sources: males having less mature immune systems versus females and variations in healthcare activities directed toward male children within this particular region.

The proportion of cases who live in rural areas surpasses the proportion of controls (56.5% versus 51.8%). However, the difference is not statistically significant, yet it matches findings from studies shows that pneumonia distribution in rural versus urban regions. [10] The analysis shows that rural living conditions, indoor combustion of biomass fuels, and overcrowding in rural homes might explain this trend.

Nutritional Status and Its Impact

The results of the nutritional status evaluation demonstrated fundamental discrepancies between children suffering from pneumonia and those without illness since pneumonia patients exhibited a higher frequency of underweight, stunting, and



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wasting. Scientific research confirms that malnutrition functions as a risk element for childhood pneumonia. (11)

Malnutrition appears more frequently among patients because of multiple existing factors. Children who have impaired functions because of malnutrition become more easily affected by infections and develop pneumonia more frequently. The relationship between malnutrition and infections forms a continuous cycle because malnutrition makes people more susceptible to infections and worsens their nutritional health (12). Third, malnutrition and pneumonia share common risk factors, such as poverty, inadequate dietary intake, and poor hygiene practices.

The research found that iron deficiency anemia maintained its relation to pneumonia development regardless of nutritional status between well-nourished and malnourished children, thus demonstrating that iron deficiency anemia functions as an independent predictor of pneumonia. The relationship between iron deficiency anemia as a risk factor for pneumonia should be recognized because undernourished individuals need iron supplementation equally as much as those who appear well nourished.

Clinical Characteristics of Pneumonia

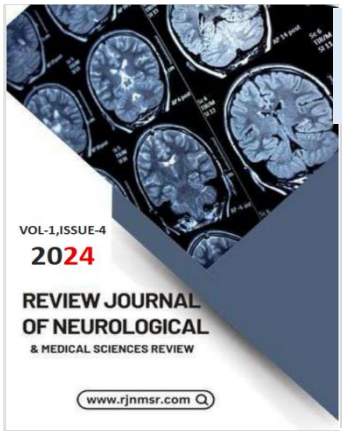
This study supported previous findings regarding pneumonia clinical grades. (12) The analysis showed that all patients experienced fever and cough followed by breathing difficulty, which affected 92.9% of patients, and tachypnea affected 95.3%. Pneumonia presents these classic symptoms, which fulfill the diagnostic criteria of pneumonia identified by the WHO for children (WHO, 2016).

According to research, half of the patients (49.4%) experienced severe pneumonia in comparable settings. (13) The prevalence of severe pneumonia might be attributed to patients arriving late at medical facilities, insufficient initial healthcare, or their extra-risk elements, including malnutrition and anemia.

The research confirmed that severe pneumonia sufferers had greater iron deficiency anemia prevalence levels at 76.2% compared to 58.1% in children with non-severe pneumonia, but statistical significance remained ambiguous (p=0.074). Mean values of hemoglobin and serum ferritin, along with transferrin saturation levels, showed meaningful variations between children with severe pneumonia and those with non-severe pneumonia. Research evidence shows that iron deficiency anemia may lead to worse pneumonia because it harms immune system functioning and oxygen distribution throughout the body. (14)

Prevalence of Iron Deficiency Anemia and Its Association with Pneumonia

Tests showed pneumonia cases had 5.51 times (95% CI: 2.86-10.63, p<0.001) the prevalence of anemia (Hb<11 g/dl) compared to healthy controls (74.1% vs. 34.1%). The prevalence of iron deficiency anemia between cases and controls showed a significant difference, with cases having higher numbers (67.1%) than controls (21.2%). The odds ratio was 7.63 (95% CI: 3.82-15.22, p<0.001). Studies support these findings, demonstrating higher anemia rates and iron deficiency anemia in patients with pneumonia. (15) (16)



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The study population shows a high general rate of anemia and iron deficiency anemia, which explains the elevated frequency observed in both cases and controls. Research indicates that worldwide, anemia affects 25 percent of people, yet the most affected group is children below five years of age (WHO, 2016).

The study results show a remarkably high association between iron deficiency anemia and pneumonia (OR=7.63, 95% CI: 3.82-15.22), which exceeds (OR=2.7, 95% CI: 1.4-5.3). Several factors, such as population variations diagnostic approaches, and medical definitions, could explain this difference between study outcomes. [17]

The research results from both studies demonstrate that iron deficiency anemia is a crucial danger factor for childhood pneumonia.

Iron deficiency anemia is an independent risk factor contributing to pneumonia development in childhood based on the results of each stepwise analysis of age, gender, residence, nutritional status, and vaccination status. The research shows the demand for iron supplementation among children with additional pneumonia risk factors.

Biological Plausibility

Research proves the complex nature of how iron deficiency anemia establishes its biological connection with pneumonia through various interrelated processes. Several immune functions require iron because lymphocytes cannot proliferate without it, natural killer cells will not function correctly, and cytokines will not develop [18] [19]. The impaired immune functions of iron deficiency make people more vulnerable to pneumonia infections.

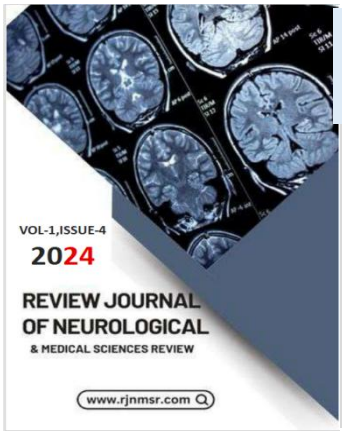
The body requires iron specifically for both oxygen transport mechanisms and cellular respiration functions. The reduction of hemoglobin levels in anemic patients restricts oxygen delivery to all body tissues, including the lungs. Under this condition, immune cell function in respiratory tissues may suffer, which amplifies pneumonia risk.

Iron deficiency anemia and pneumonia share a similar vulnerable population because poverty, lack of proper nutrition, and poor hygiene practices affect both conditions. Children with iron deficiency anemia who experience these factors have an increased potential for developing pneumonia.

Strengths and Limitations

This investigation stands strong due to its case-control structure because it evaluated pneumonia connections to iron deficiency anemia and addressed potential bias factors. Serum ferritin and transferrin saturation are superior diagnostic tools for iron deficiency anemia compared to conventional hemoglobin measurements since they are more accurate in evaluating body iron levels.

The research encounters various restrictions as part of its analysis. The nature of the study as case-control prevents it from proving that iron deficiency anemia leads to pneumonia development. The research took place at only one hospital, which might reduce the study's ability to apply results outside this setting. The research compensated for confounders via matching approaches, yet residual confounding sources might continue to affect the results. This research failed to evaluate



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additional pneumonia risk elements, including home air contamination, house density, and breastfeeding methods.

Findings And Conclusion

Prevalence of Iron Deficiency Anemia in Children with Pneumonia

The research data shows that pneumonia patients display remarkably elevated iron deficiency anemia rates compared to healthy children. The research established that pneumonia in children affected iron intake at 67.1%, while healthy controls maintained normal iron levels at 21.2%. The 7.63 odds ratio (95% CI: 3.82-15.22, $p<0.001$) established that pneumonia patients have more than seven times higher risk of developing iron deficiency anemia than healthy children. Primary healthcare professionals should focus on implementing specific interventions for at-risk populations since evidence reveals iron deficiency anemia plays a significant role in pneumonia development among children.

Independent Risk Factor for Pneumonia

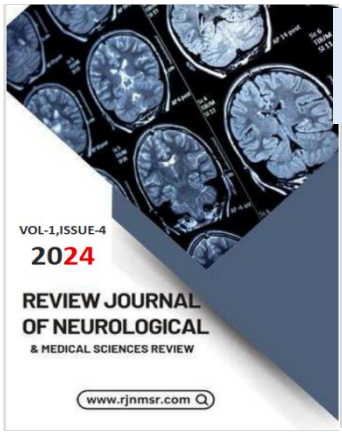
The relationship between iron deficiency anemia and pneumonia persisted throughout additional demographic and health-relevant factor stratification of the data, including age, gender, residence type, nutrition status, and vaccination status. The thorough analysis confirms the role of iron deficiency anemia as an independent risk factor because it eliminates its association with pneumonia. The data shows that improving iron deficiencies represents a vital opportunity to decrease pneumonia among children while bypassing other potential factors. Healthcare professionals should implement structured pediatric practices to screen and treat iron deficiency anemia because evidence shows such intervention benefits children with an increased risk of respiratory infections.

Severity of Pneumonia and Iron Deficiency Anemia

Researchers investigated how severe pneumonia cases relate to iron deficiency anemia. The analysis showed that severe pneumonia cases contained a rate of iron deficiency anemia at 76.2%, while non-severe pneumonia cases only carried a rate of 58.1%. Even though this difference stopped short of reaching statistical value ($p=0.074$), it suggests vital questions about the influence of iron deficiency on pneumonia development. The result shows that pneumonia severity correlates with the prevalence of iron deficiency anemia because seriously ill children may face more significant risks of nutritional deficiencies. Additional studies should analyze whether better iron status would affect the medical results in children who suffer from pneumonia.

Hemoglobin Levels and Iron Status Indicators

Research findings revealed important variations between children with different pneumonia severity levels because they showed divergent results for hemoglobin concentrations and serum ferritin along with transferrin saturation measurements. The biochemical markers provide essential information about the state of iron within the body and anemic conditions. Patient recovery and general health outcomes become complicated when severe pneumonia patients demonstrate lower blood hemoglobin levels and reduced serum ferritin measurements since these iron deficiency signs indicate advanced disease forms. The study reveals substantial



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findings about children with pneumonia by demonstrating that iron deficiency anemia exists widely between such patients and showing its potential connection with worsened disease severity. Regular assessments of iron levels in children with respiratory infections need attention because immediate treatment should minimize severe pneumonia-related complications.

Malnutrition and Pneumonia

Research findings displayed an alarming situation regarding child malnutrition in pneumonia cases since the grades of underweight and stunting and wasting occurred more frequently in this group versus healthy control subjects. Research shows that children with pneumonia often present malnutrition, supporting the close connection between these health conditions. The medical challenges from simultaneous pneumonia and malnutrition problems for children intensify because malnutrition worsens infection severity and delays recovery time. Implementing complete nutritional programs must become a priority because it can potentially decrease child pneumonia cases. Successful dietary habits and nutritional status improvement need specialized interventions to decrease pneumonia's impact on vulnerable populations.

The Role of Vaccination

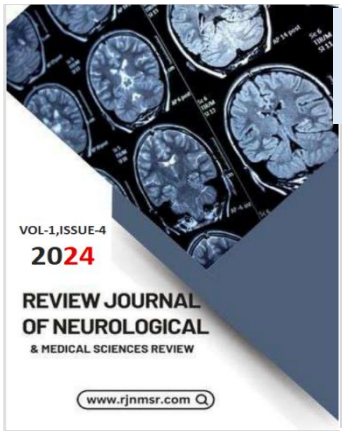
Results from the research demonstrated that children who had pneumonia identified more frequently received incomplete vaccinations compared to children without pneumonia conditions. The research findings show that vaccination is a vital tool against pneumonia, thus demonstrating that better vaccination rates could decrease the incidence of pneumonia in children. Public health efforts must focus on complete childhood vaccination since vaccines protect people from pneumonia-causing common pathogens. Health authorities should prioritize vaccinations through targeted programs because the connection between the non-completion of vaccines and pneumonia development proves its critical importance. Children need parents and caregivers to receive accurate vaccination schedule instructions to defend their well-being.

Conclusion and Implications for Public Health

Evidence presented in this study establishes that pneumonia among children shows high rates of iron deficiency anemia, which presents as an independent disease risk factor. The research data confirm the need for pediatric healthcare to manage iron deficiency anemia by screening patients, treating malnutrition, and providing all required vaccinations. Public health initiatives should develop unified programs that integrate these factors to fight pneumonia among children. Better collaboration between healthcare professionals nut, nutritionists, and public health officials will improve health results for high-risk populations, subsequently cutting down pneumonia cases among children. Future research needs to study the root causes of iron deficiency anemia and pediatric pneumonia and create specific intervention methods that tackle both conditions simultaneously.

Conclusion

A case-control research shows strong proof that iron deficiency anemia and pneumonia create significant joint health risks for children under five. According to



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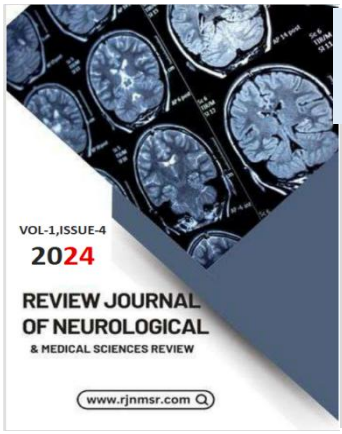
results from this study, Children diagnosed with pneumonia show a 7.63 times greater chance of suffering from iron deficiency anemia. This important public health figure emphasizes a crucial threat to young children because it illustrates their combined exposure to both disorders and indicates they may cause each other. The relationship between pneumonia and iron deficiency anemia proved statistically significant after validating the study by excluding influential factors such as age among patients and their gender and nutritional health status and recorded vaccination histories. This study's reliable results confirm that iron deficiency anemia functions as an independent risk factor for developing pneumonia because it exceeds statistical associations based on pneumonia and iron deficiency anemia coexistence.

Research results indicate that iron deficiency anemia affects many pneumonia patients and the tested healthy volunteer population. The reported iron deficiency anemia in the healthy control group demonstrates that this nutritional deficiency is common across the population, presumably because of economic and dietary challenges and healthcare service limitations. Public health organizations must adopt extensive intervention strategies to enhance children's iron status because pneumonia and anemia are common in vulnerable regions.

The relationship between pneumonia and iron deficiency anemia becomes especially serious since children under five years are susceptible to respiratory infections due to immature immune development. People who experience pneumonia, together with iron deficiency anemia, develop higher rates of health complications, which may result in fatal outcomes. Health organizations must establish a complex pediatric health plan containing iron deficiency screening protocols during regular check-ups, explicitly targeting high-risk demographic groups. Early diagnosis and appropriate treatment of iron deficiency anemia can decrease the frequency and intensity of pneumonia affecting young children.

The biological explanation of this connection serves as strong evidence to demonstrate that iron deficiency anemia presents an essential risk factor for pneumonia development in children. The vital physiological function of iron supports both immune cell operations and blood oxygen delivery to all body tissues. The development and multiplication of immune cells, particularly lymphocytes, require iron as an essential component for their proper growth because lymphocytes serve as the key defense against infections. The immune system performs inadequately in iron-deficient individuals because of compromised immunity, making them more likely to get infected, including pneumonia. A deficient amount of iron decreases the body's ability to synthesize hemoglobin, which causes impaired oxygen transport, thus making respiratory illnesses more severe.

The biological pathways that develop from iron deficiency anemia demand immediate attention when minimizing pneumonia-related health problems in children. The public health approach should focus on supporting the consumption of iron-rich foods and supplements, primarily among groups identified as deficient. Educational initiatives targeting parents and caregivers regarding child nutrition and iron value and identifying iron deficiency symptoms would enable them to obtain intervention at the right time.



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Specific health intervention programs can effectively decrease pneumonia rates when iron supplementation programs run parallel to vaccination services and healthcare delivery. Additional nutritional interventions and preventive public health measures combined into one child health approach will help health authorities develop effective methods for preventing pneumonia cases and enhancing the overall wellness of vulnerable populations.

The results show a significant link between iron deficiency anemia in young children and pneumonia occurrence, so public health must focus its intervention efforts on treating nutritional deficiencies. Interventions that combine screening procedures with education and supplementation programs should become standard to strengthen child resistance against pneumonia and improve health results in this high-risk group. Stakeholders will achieve better pediatric healthcare outcomes by recognizing interconnected health issues and implementing an integrated prevention and treatment strategy.

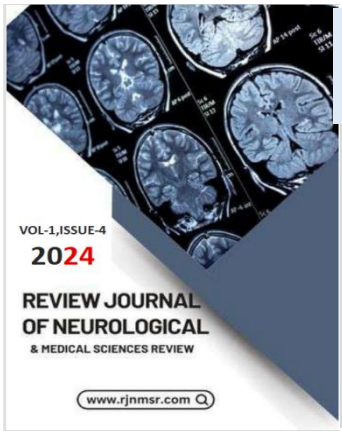
Recommendations

A series of recommendations resulting from this research investigation:

1. Child health programs across all territories should implement routine screening for iron deficiency anemia, particularly in regions with high pneumonia rates.
2. All children with iron deficiency anemia should receive iron supplements because the status of their nutrition or risk factors for pneumonia will not determine their eligibility.
3. Multiple strategies that address iron deficiency anemia and malnutrition need implementation because these medical conditions frequently overlap, resulting in a higher pneumonia risk rate.
4. The findings of this study support enhancing vaccination programs because partial immunization increases pneumonia development among patients.
5. Researchers should undertake prospective cohort studies and randomized controlled trials to determine the causal connection between iron deficiency anemia and pneumonia and to understand how iron supplementation influences pneumonia rates and severity in children.
6. Health education aimed at parents and caregivers must instruct them on the importance of a diet rich in iron, timely vaccinations, and prompt recognition of pneumonia signs to decrease pneumonia-related deaths and health problems.
7. Reducing the burden of iron deficiency anemia and pneumonia incidence requires policy actions that target vulnerable populations through interventions into social health determinants, including poverty, food access issues, and healthcare accessibility.
8. Healthcare providers need improved training in diagnosing iron deficiency anemia and its pneumonia-causing complications to enhance patient care.

Future Research Directions

Future research requires investigation into various important directions based on the findings of this study.



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1. Researchers should perform long-term observational studies to prove that iron deficiency anemia causes pneumonia while demonstrating the effects of treating this anemia on pneumonia occurrence.
2. The research examines how iron supplements guard against pneumonia development in children with iron deficiency anemia through randomized controlled trials.
3. Research should determine how iron deficiency anemia enhances a person's vulnerability to pneumonia.
4. Research teams must study additional potentially harmful factors for child pneumonia, including indoor pollution, home overcrowding, and breastfeeding approaches concerning iron deficiency anemia.
5. Studies must explore the best methods to combat iron deficiency anemia across different environments based on standard attributes like malaria distributions and other illness development risks associated with iron supplements.
6. Researchers must study how combined interventions tackling pneumonia precursor factors such as iron deficiency anemia, malnutrition, and incomplete vaccination prevent pneumonia.
7. A study will analyze the financial benefit of testing and treating patients for iron deficiency anemia to lower child pneumonia incidence rates.

The intense research findings show that iron deficiency anemia increases the risk of pneumonia in children younger than five. The diagnosis and suitable management of iron deficiency anemia before symptoms appear to bring significant benefits toward decreasing the high pneumonia-related mortality rate in children. Improving child health outcomes in developing countries requires complete strategies simultaneously managing iron deficiency anemia and pneumonia risk elements, including malnutrition and incomplete vaccinations.

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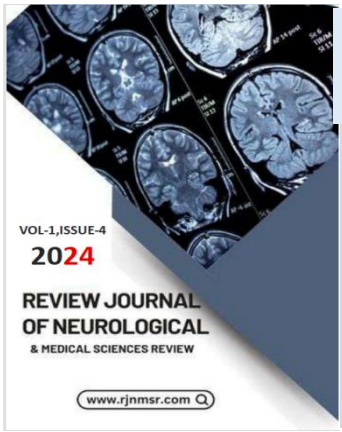

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