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Multivariate Prediction of NICU Admission Based on Maternal and Intrapartum Risk Factors

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ABSTRACT

Background: Neonatal intensive care unit (NICU) admission is a significant outcome of the process of providing perinatal care. This outcome often correlates with severe morbidity of the newborns. Awareness of risk factors concerning the mother and pregnancy generally helps to address the situation appropriately. To determine the maternal and obstetric predictors independently associated with NICU admission in singleton deliveries using multivariate statistical analysis.

Methods: This was a retrospective, analytical cross-sectional study of 2,511 singleton deliveries. Bivariate comparisons were conducted using chi-square tests and t-tests, followed by multivariate logistic regression to identify independent predictors. Odds ratios (OR), confidence intervals (CI), area under the ROC curve (AUC), and variance inflation factors (VIF) were reported.

Results: NICU admissions occurred in 322 neonates (12.8%). The primary predictors of NICU admissions, after adjustment for all other terms, included cesarean delivery, with an AOR of 48.7; advanced maternal age >35 years, with an AOR of 18.2; prolonged labor >12 hours, with an AOR of 8.1; preterm birth, with an AOR of 6.6; and hypertensive crisis, with an AOR of 3.7. The model demonstrated good prediction accuracy with an AUC of 0.95.

Conclusion: Advanced maternal age, hypertensive crisis, cesarean delivery, preterm birth, and long labor have emerged as significant predictors of NICU admission.

Keywords: C*esarean section, Hypertensive crisis, Intensive Care Units, Infant, Logistic models, Newborn, Pregnancy outcome, Risk factors*

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INTRODUCTION

In Pakistan, the neonatal mortality rate is high, i.e., 37.6 per 1,000 live births, registering an average of 246,300 neonatal deaths every year[1]. This ranks the country third in the world, which alone accounts for about 7% of all neonatal deaths globally[2], while the target of the sustainable goal is only 12 per 1,000 live births. Neonatal Intensive Care Unit (NICU) admission is a vital surrogate indicator of neonatal morbidity and an important determinant of short-term and long-term infant outcomes. NICU admission has been predominantly related to pre-term births, respiratory distress, and perinatal asphyxia. However, with recent studies, there has been a focus on highlighting term and near-term NICU admissions from maternal, fetal, and intrapartum complications.

Risk factors such as, advanced maternal age, especially over 35 years, has emerged as a critical determinant of admission to the NICU. A recent study from China developed a predictive nomogram that included AMA, fetal distress, preterm birth, and hypertensive disorders to predict NICU transfers with high discriminative ability[3]. European cohort studies have reported that maternal age was significantly higher for the cases that were admitted to the NICU, though age was not retained as an independent predictor after adjustment for confounders[4].

Similarly, hypertensive disorders of pregnancy, especially early-onset preeclampsia and eclampsia, were significantly associated with NICU admission. This was mainly due to preterm birth and low birth weight in term infants[5]. Preterm birth remains the most important independent predictor of admission to the NICU, being strongly related to very early gestational age, since it increases the need for respiratory and metabolic support as a consequence of complications such as respiratory distress syndrome and pulmonary hypoplasia[6].

Additional factors leading to admission in NICUs include cesarean delivery (LSCS), low birth weight babies, abnormal AFI values, and complications in the mother. The attributes from the studies were identified as vital predictors of admission in the

NICU using a decision tree-based approach from Panda et al., in which aspects were predicted as high by the decision tree model than in other approaches[7]. The multivariable factors highlight the total deficiency of basing assessments strictly on single variables and require multivariable assessments in order to pinpoint independent predictors.

Therefore, the current study applied logistic regression modeling methods to examine the adjusted role of these risk factors such as maternal age, type of delivery, hypertensive crisis, gestational age, and prolonged labor for NICU admissions. The significance of these correlations could help guide healthcare workers in the early identification of at-risk pregnant women.

METHODOLOGY

Study Design and Setting

It was a retrospective, analytical cross-sectional study conducted in the Department of Obstetrics and Gynecology, Shafiq Medical Center, Larkana, from February 2024 to July 2024.

Study Population and Eligibility Criteria

A total of 2,511 singleton deliveries were involved in the study. The eligible records included singleton gestations delivered at a viable gestational age (≥24 weeks) with complete documentation of maternal demographics, antenatal and intrapartum clinical parameters, mode of delivery, and neonatal outcomes. Records of multiple gestations, congenital anomalies, stillbirths, or incomplete data were excluded to minimize bias due to confounding and missing data. Regarding the primary outcome, neonates were categorized into NICU-admitted (n = 322) and non-NICU groups (n = 2,189) for comparison.

Data Source and Data Quality Control

The data repository had its foundation in a standard electronic patient registry maintained by the Department of Obstetrics and Gynecology. All continuous data had been originally collected using standard clinical protocols. For statistical analysis purposes, data had been dichotomized retrospectively according to a relevant variable selection criterion to aid in logistic modeling and estimations.

Outcome Variable

The main dependent variable of interest for analysis was defined as **Neonatal Intensive Care Unit (NICU) admission**, which was coded as a binary outcome (Yes = 1, No = 0). This was defined based on clinical documentation at the time of delivery and represents the urgent need for specialized neonatal care due to perinatal complications or instability.

Predictor Variables

Independent variables were selected a priori, grounded in established obstetric literature and recent empirical studies. Each predictor represented a clinically meaningful risk factor for adverse neonatal outcomes and was defined as follows:

Cesarean Section (C-Section)

Mode of delivery was categorized as cesarean (elective/emergent) versus vaginal delivery. Several studies found that cesarean birth, especially elective cesarean, is significantly associated with the risk of respiratory illness in the newborn and the likelihood of admission to the NICU[8].

Advanced Maternal Age (≥35 years)

Age was considered as a binary variable; the critical value taken was 35 years. Advanced maternal age is known to cause certain pregnancy-related complications like preeclampsia and gestational diabetes, which in turn cause increased NICU admissions[9].

Preterm Birth

Delivery before the completion of 37 weeks of gestation. Neonates born prematurely often need to be admitted to a NICU because their major organ systems are incompletely developed and they are at significant risk for complications associated with respiratory distress syndrome and sepsis[6].

Prolonged Labor

Total duration of active labor exceeds 12 hours (as recorded in the obstetric progress note). Prolonged labors are associated with a high risk of neonatal asphyxia, fetal distress, and subsequent NICU admissions as evidenced by machine learning-based models for risk prediction[7].

Hypertensive Crisis

It was defined according to the American College of Obstetricians and Gynecologists (ACOG) standards, including systolic blood pressure ≥180 mmHg and/or diastolic blood pressure ≥120 mmHg during labor or before delivery. Severe hypertensive conditions, including preeclampsia and eclampsia, are associated with increased risks to neonates who are admitted to NICU[10]. All continuous variables were collected, and the initial data were recorded by standardized clinical protocols. However, for the purpose of inferential analysis, all the relevant variables were post hoc dichotomized for the ease of logistic modeling.

Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics version 25 (IBM Corp., Armonk, NY)[11, 12] .

The primary outcome variable was Neonatal Intensive Care Unit (NICU) admission, analyzed as a binary categorical endpoint (Yes = 1, No = 0).

The following statistics were calculated to describe key maternal and obstetric parameters: for continuous variables (maternal age, systolic and diastolic blood pressure, gestational age at delivery, labor duration), means and SD were reported according to NICU and non-NICU groups. This measure allowed for an overall view of the averages of the series and their dispersions[9].

To explore associations between NICU admission and each predefined clinical risk factor, bivariate analyses were conducted. Continuous variables were compared using independent samples t-tests, under the assumption of normality[13]. Categorical variables such as cesarean section, preterm birth, hypertensive crisis, advanced maternal age (≥35 years), and prolonged labor were assessed using chi-square tests of independence[14.] In instances of low expected cell counts, Fisher's exact test was employed. Crude odds ratios (ORs) with 95% confidence intervals (CIs) were computed using standard 2 × 2 contingency tables to quantify unadjusted effect sizes[15].

Next, multivariate binary logistic regression was done to find independent predictors of admission to the neonatal intensive care unit (NICU). The clinically relevant binary variables are entered simultaneously into the prediction equation. The method used for analysis was the forced entry method. The results included adjusted odds ratios, 95% confidence intervals, and the p-values. The method estimates the effects of all independent variables, holding all other independent variables constant[16].
Model discrimination was evaluated using receiver operating characteristic (ROC) curve analysis. The area under the ROC curve (AUC) was used to assess overall predictive performance, while sensitivity, specificity, and optimal probability thresholds were calculated using Youden's index as a decision criterion[17, 18].

To evaluate multicollinearity among independent variables, variance inflation factors (VIFs) were computed. VIF values below 5 were interpreted as indicating an acceptable level of collinearity, ensuring the stability and interpretability of regression estimates[19,20] .

All statistical tests were two-sided, and a p-value< 0.05 was considered statistically significant.

Ethical Considerations

The study was conducted in accordance with the ethical standards of the Declaration of Helsinki. Ethical approval was granted by the Ethics Review Committee of Shafiq Medical Center, Larkana (Approval Number: B75C167E). The approval covered the period from 05 February 2024 to 13 July 2024. As this was a retrospective secondary analysis of anonymized data, formal informed consent was not applicable.

RESULTS

Descriptive Analysis

There was a notable difference between the groups regarding the clinical and demographic factors of the neonates admitted to the NICU and those not admitted. Specifically, it was noted that the age of the mothers of the neonates admitted to the NICU was significantly higher, with the overall average age of the group being approximately 38.26 years, as opposed to 27.06 years, which was the overall average age of the group not admitted to the NICU, demonstrating a wider range due to the higher standard deviation within the group of the older age demographic; moreover, the blood pressure was significantly higher within the NICU group, with 167.69/113.76 mmHg representing the overall blood pressure of the group, as opposed to 116.80/74.42 mmHg.

The gestational age at delivery was lower for NICU admissions, 32.39 weeks, compared to non-NICU cases, 36.59 weeks, thereby underlining the crucial role of preterm birth in neonatal morbidity. In addition, prolonged labor was much higher in the NICU group, with an average duration nearly double that of non-NICU deliveries, at 18.20 versus 9.33 hours, respectively. As demonstrated in the results depicted in the Table 1.

Table 1: Descriptive Statistics by NICU Admission Status

	NICU No (n=2189)		NICU Yes (n=322)	
Variable	**Mean**	**SD**	**Mean**	**SD**
Maternal Age (years)	27.06	6.00	38.26	4.76
Systolic BP (mmHg)	116.80	18.27	167.69	16.95
Diastolic BP (mmHg)	74.42	10.75	113.76	14.41
Gestational Age (weeks)	36.59	4.21	32.39	2.88
Labor Duration (hours)	9.33	6.09	18.20	3.85

Abbreviations: NICU, Neonatal Intensive Care Unit; SD, Standard Deviation; BP, Blood Pressure

Bivariate Clinical Summary

Cesarean sections were performed in nearly 70% of NICU cases and only 2.5% of controls, respectively, they were associated with high-risk deliveries. Preterm births were overwhelmingly represented in the NICU group (96.0%)

compared to non-NICU (39.7%).
Similarly, hypertensive crises were evident in 48.4% of NICU cases versus just 2.9% in non-NICU cases. Advanced maternal age ≥ 35 years and prolonged labor also followed a similar pattern; hence, the importance of their consideration for obstetric risk profiling is enhanced. The frequency distribution of binary risk factors summarized in Table 2 shows an excessive burden of adverse maternal conditions in the group of NICU admissions.

Table 2: Frequencies of Risk Factors by NICU Admission

Risk Factor	NICU Yes (%)	NICU No (%)
Cesarean Section	224 (69.6%)	54 (2.5%)
Preterm Birth	309 (96.0%)	868 (39.7%)
Hypertensive Crisis	156 (48.4%)	63 (2.9%)
Maternal Age ≥35	285 (88.5%)	316 (14.4%)
Prolonged Labor	295 (91.6%)	579 (26.5%)

Crude Associations and Odds Ratios

Delivery via cesarean section had an unadjusted OR of 90.37 (95% CI: 63.08–129.47), reflecting that neonates delivered by C-section had far greater odds of being admitted to NICU. The crude associations of preterm birth, hypertensive crisis, maternal age ≥ 35 years, and prolonged labor with admission to NICU were also strong, ranging from 30.38 to 45.66. Crude odds ratios in Table 3 quantitatively reinforced these relationships.

Table 3: Crude Odds Ratios for NICU Admission

Risk Factor	Exposed	Unexp Yes	Unexp No	Crude OR (95% CI)
C-section performed	278	98	2135	90.37 (63.08–129.47)
Preterm birth	1177	13	1321	36.17 (20.63–63.42)
Hypertensive crisis	219	166	2126	31.71 (22.74–44.22)
Maternal age ≥35	601	37	1873	45.66 (31.77–65.61)
Prolonged labor	874	27	1610	30.38 (20.26–45.57)

Multivariable Logistic Regression

Cesarean delivery remained the most significant predictor on its own (AOR = 48.7; 95% CI: 26.6-89.2; $p < 0.001$). Advanced maternal age, preterm birth, and abnormal labor were also statistically significant predictors in their own right (AOR = 18.2, 6.6, and 8.1, respectively). Notably, hypertensive crisis-maintained significance (AOR = 3.7; $p = 0.007$). The adjusted logistic regression model values are shown in Table 4.

Table 4: Multivariable Logistic Regression for NICU Admission

Variable	Adjusted OR	95% CI	p-value
C-Section	48.7	26.6–89.2	<0.001
Hypertensive Crisis	3.7	1.4–9.7	0.007
Preterm Birth	6.6	3.1–14.0	<0.001
Maternal Age ≥35	18.2	10.6–31.2	<0.001
Prolonged Labor	8.1	4.3–15.3	<0.001

Model Discrimination and ROC Thresholds

The logistic regression model showed excellent discriminatory capability for NICU admission decision, as indicated by an area under curve > 0.95. With an optimal probability cutoff of 0.60, the model showed a sensitivity of 79.8% and specificity of 87.4%, indicating efficient detection of vulnerable neonates while ruling out false positive cases. As given in the Table 5.

Table 5: ROC Threshold Performance Metrics

Threshold	Sensitivity (%)	FPR (%)	Specificity (%)	Youden Index
0.60	79.8	12.6	87.4	67.2

DISCUSSION

Five variables were found, which were independent predictors for admission to NICUs for singleton pregnancies. After this study, evidence supports the inclusion of multivariate risk analysis in clinical pathways. A discriminatory ability was found to be high for the model, i.e., AUC > 0.95, and no signs of multicollinearity were found.

These findings are in agreement with previous literature. Socol et al[21]. also reported maternal age and hypertensive disorders as significant contributors to neonatal complications. Cesarean section appeared as the most powerful predictor[22], which might reflect both elective and emergency indications related to underlying maternal or fetal compromise. Battarbee et al[23]. identified preterm birth as one of the most important predictors of extended NICU stay. The finding of an association between hypertensive crisis and NICU admission is in agreement with previous reports of an association between severe preeclampsia and neonatal morbidity[24]. Similarly, preterm birth continues to be an important determinant for NICU utilization, largely due to respiratory and neurological immaturity. Prolonged labor showed significant association, likely reflecting fetal distress and dystocia in labor, as per findings from Northeast Ethiopia[25].

Khasawneh et al.[26] also linked cesarean section

to increased NICU admissions. Advanced maternal age retained a strong independent effect, possibly reflecting cumulative comorbidities and age-related placental dysfunction, as demonstrated by multiple studies[3,27]. Hypertensive complications contribute significantly to adverse neonatal outcomes, even after adjustment in large multicenter cohorts[28]. Multiple studies have identified maternal and neonatal outcome risk models with comparable discriminatory performance and identified these variables as predictors of adverse neonatal outcomes[29,30]. These predictors are based on routine clinical observations, enhancing the feasibility of real-time risk scoring in practice.

These results are of particular relevance to Pakistani and LMIC demographics where neonatal mortality is considerable and access to well-equipped NICUs is limited. The identification of high-risk pregnancies using clinical variables may contribute to risk stratification of pregnant populations and support healthcare resource allocation decisions. Application of these predictors in clinical work may ultimately prove useful sources of support for clinical and midwife staff in the prevention and management of NICU admissions.

Strengths and Limitations:

One of its biggest advantages lies in its 'robust statistical framework that includes support for bivariate screening, multivariate modeling, and ROC optimization'; however, its weaknesses might include its retrospective nature and lack of certain factors, such as APGAR or neonatal diagnoses. Moreover, it only shows factors from one medical center.

CONCLUSION

The current research found cesarean section (AOR: 48.7), older maternal age ≥ 35 years (AOR: 18.2), prolonged labor (AOR: 8.1), preterm birth (AOR: 6.6), and hypertensive crisis (AOR: 3.7) to be significant independent predictors of NICU admission. The logistic regression model had a high discriminatory power (AUC > 0.95), which makes it suitable for use as a decision-support tool. These results highlight the importance of increased antenatal and intrapartum surveillance for high-risk pregnancies. Future studies should aim to confirm these predictors in prospective studies and establish an obstetric risk scoring system to aid in NICU triage.

Ethical Approval

The study was by the Ethics Review Committee of Shafiq Medical Center, Larkana (Approval Number: B75C167E).

Author Contributions

SW: Conception & Design, Data Collection, Data Analysis & Interpretation, Manuscript Writing, Critical Revision

SW: Data Collection Data Analysis & Interpretation, Manuscript Writing, Critical Revision

A: Data Analysis & Interpretation, Manuscript Writing

All authors approved the final version of the manuscript to be published.

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None.

Conflict of Interests

No conflict of interest.

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