ADDIS ABABA UNIVERSITY



COLLEGE OF HEALTH SCIENCES
DEPARTMENT OF PEDIATRICS AND CHILD HEALTH

RESEARCH THESIS DRAFT

Development of a Clinical Risk Assessment score for Early Prediction of Neonatal Mortality at a selected hospital, Addis Ababa, Ethiopia: A Case-Control Study

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A research proposal to be submitted to Addis Ababa university, college of health sciences; department of pediatrics and child health in partial fulfilment of the requirement for the specialty certificate program in pediatrics and child health.

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Research Proposal Approval Form

"Development of a Clinical Risk Assessment Score for Early Prediction of Neonatal Mortality at TASH, Addis Ababa, Ethiopia: A Case-Control Study"

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Mentor's Approval Statement:

I have reviewed the above-mentioned research proposal and found it to be satisfactory in terms of its scientific content, feasibility, and ethical soundness. I therefore approve it for submission to the Institutional Review Board (IRB).

_____

Dr. Rahel Argaw (Mentor)

Signature: _____

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_____

Dr. Tsegaab Fikre (Investigator)

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List of Acronyms

AAP - American Academy of Pediatrics
AOR - Adjusted Odds Ratio
CI - Confidence Interval
CRIB - Clinical Risk Index for Babies
LMIC - Low- and Middle-Income Countries
NICU - Neonatal Intensive Care Unit
NMR - Neonatal Mortality Rate
SNAP - Score for Neonatal Acute Physiology
TASH - Tikur Anbessa Specialized Hospital
WHO - World Health Organization
ENM- Early neonatal mortality
LNM -Late neonatal mortality

Abstract

Background: Neonatal mortality remains a major public health challenge in Ethiopia despite substantial improvements in maternal and child health services. Early identification of neonates at high risk of death is essential for timely intervention and optimal allocation of limited neonatal intensive care resources. However, standardized and locally validated prognostic tools for predicting neonatal mortality are scarce in Ethiopian neonatal intensive care units (NICUs).

Objective: To develop and internally validate a clinical risk assessment score for early prediction of neonatal mortality among neonates admitted to the NICUs of Tikur Anbessa Specialized Hospital (TASH) and Gandhi Memorial Hospital (GMH), Addis Ababa, Ethiopia.

Methods: A hospital-based retrospective case–control study was conducted among 570 neonates admitted to the NICUs of TASH and GMH between March 2025 and January 2026. Cases were neonates who died during NICU admission (n = 189), while controls were neonates discharged alive (n = 381). Data were extracted from medical records using a structured data abstraction tool. Bivariable and multivariable logistic regression analyses were performed to identify independent predictors of neonatal mortality. Variables with $p < 0.25$ in bivariable analysis were entered into the multivariable model. Model performance was assessed using calibration and goodness-of-fit statistics. A simplified clinical risk score was developed from the regression coefficients of significant predictors.

Results: Of the 570 neonates included in the study, 33.2% died during NICU admission. Multivariable logistic regression identified meconium aspiration syndrome (MAS) (AOR = 4.10; 95% CI: 1.61–10.40), gestational age of 28–32 weeks (AOR = 5.41; 95% CI: 1.57–18.66), birth

weight of 1000–1499 g (AOR = 6.94; 95% CI: 1.88–25.64), and need for bag-and-mask resuscitation at birth (AOR = 4.83; 95% CI: 1.50–15.54) as independent predictors of neonatal mortality. A risk score ranging from 0 to 7 points was developed based on these predictors. The model demonstrated good calibration (Hosmer–Lemeshow $\chi^2 = 6.70$, $p = 0.570$) and acceptable predictive performance, explaining 53% of the variability in neonatal mortality (Nagelkerke $R^2 = 0.53$).

Conclusion: Meconium aspiration syndrome, prematurity, low birth weight, and the requirement for bag-and-mask resuscitation at birth were significant predictors of neonatal mortality among NICU admissions. The developed clinical risk score is simple, practical, and based on readily available clinical variables, making it suitable for bedside risk stratification in resource-limited settings. External validation in diverse healthcare settings is recommended before widespread implementation.

Keywords: Neonatal mortality, Risk prediction model, Clinical risk score, Prematurity, Low birth weight, Meconium aspiration syndrome, NICU, Ethiopia.

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First and foremost, I would like to thank Almighty God for granting me the health and wisdom to accomplish this work. I am deeply grateful to my advisor, Dr. Rahel Argaw, for her invaluable guidance, constructive comments, and continuous support throughout the development of this proposal. My appreciation also extends to the Department of Pediatrics and Child Health, Addis Ababa University, for providing the opportunity and resources to conduct this study. Lastly, I thank my family and colleagues for their encouragement and moral support.

1. Introduction

1.1 Background

The neonatal mortality rate (NMR), defined as the death of a neonate within the first 28 days of life and expressed per 1,000 live births, remains a significant public health challenge globally (1).Neonatal mortality is divided into two main categories. Early neonatal mortality (ENM) refers to the death of a newborn within the first seven days of life, while late neonatal mortality (LNM) describes deaths that occur between the 7th and 28th day after birth. In 2023, roughly 4.8 million children under the age of five died worldwide—among them, about 2.3 million newborns in their first 28 days of life, underscoring how the first month remains the most fragile period in a child's life (2). Despite ongoing interventions, underreporting of deaths—particularly in Africa where 62% of deaths go unrecorded—impedes accurate assessment and timely action (3). Alarmingly, around 6,700 neonates die daily, with nearly one-third of these deaths occurring on the first day of life, and about 75% within the first week (4, 5).

Although global efforts have reduced NMR by 51% between 1990 and 2017, regions like West and Central Africa and South Asia continue to experience the highest rates (6). The neonatal mortality rate in these areas is more than nine times that of high-income countries. South Asia and sub-Saharan Africa share 79% of the global neonatal death burden, with South Asia alone accounting for 38%, and East and South Africa contributing around 18% (6, 7). Ethiopia is among the six countries responsible for half of the world's under-five mortality, ranking as one of the top ten countries with the highest neonatal mortality, with an estimated 122,000 newborn deaths annually—constituting two-thirds of the global neonatal death toll (8–10).

Neonatal mortality is influenced by the timing of death, with distinct etiological patterns observed across early and late neonatal periods. Prematurity remains the predominant cause of early neonatal deaths, reflecting complications associated with underdeveloped organ systems and limited access to advanced neonatal care. In contrast, birth asphyxia is more frequently implicated in late neonatal mortality, often resulting from intrapartum complications or delayed resuscitation. Additionally, respiratory distress syndrome (RDS) continues to be a significant contributor to neonatal deaths across both timeframes, underscoring the need for timely diagnosis and intervention (11–13). Other important factors include birth injury, hyperthermia, neonatal infections, and birth asphyxia, which affect both early neonatal mortality and late neonatal mortality (14–16).

Additional risk factors relate to maternal and perinatal conditions such as maternal age, parity, pregnancy interval, multiple gestations, maternal health issues during pregnancy, fetal malpresentation, complications during delivery, and infant sex (17, 18).

Global and national efforts to decrease neonatal mortality have incorporated the Millennium Development Goals (MDGs) and the ongoing Sustainable Development Goals (SDGs), targeting improvements in child survival (19, 20). Ethiopia has notably advanced its health sector through programs enhancing institutional delivery rates, antenatal care coverage, and postnatal care within 48 hours of birth (21). Strategies such as emergency obstetric and newborn care have also contributed to reducing maternal and under-five mortality (22, 23). Despite these efforts, reductions in neonatal mortality have been comparatively modest (24).

Developing clinical prediction models that integrate multiple risk factors can significantly aid neonatal care by estimating individual mortality risk in neonatal intensive care units. These models support personalized decisions and enable early identification of high-risk neonates for timely intervention (25–27). In recent years there are a couple of researches with aim of developing a predictor tool and internally validate in Ethiopia. Validation is crucial for accurately pinpointing at-risk infants and guiding resource allocation. Hence, this study aims to identify key predictors of neonatal death to inform policymakers and healthcare organizations, facilitating effective interventions to reduce neonatal mortality.

1.2 Statement of the Problem

Neonatal mortality is a persistent problem in Ethiopia despite reductions in under-five mortality.At present, there is no standardized or externally validated prognostic tool routinely used in neonatal intensive care units across Ethiopia. However, several initiatives are underway at leading university hospitals, such as Hawassa University Comprehensive Specialized Hospital (HUCSH) and the University of Gondar (UoG) Hospital, aimed at developing and validating a nationally applicable neonatal mortality prediction tool (41,42). Clinicians often rely on subjective assessments, which may delay timely interventions. This research aims to fill this gap by developinga prognostic score model which predict at risk neonates in the largest referral hospitals in Addis Abeba Ethiopia.

1.3 Significance of the Study

This study will help in providing a prognostic score to identify at risk neonates of death at neonatal period which is applicable to Ethiopian NICUs, enabling clinicians to identify high-risk neonates early (41). It will improve timely interventions, guide resource allocation, and contribute to reducing neonatal mortality. Additionally, it will serve as a foundation for future multicenter validations in Ethiopia

2. Literature Review

Neonatal mortality, defined as the death of an infant within the first 28 days of life, continues to be a major public health challenge worldwide, especially in low- and middle-income countries. It is distinctly classified into early neonatal mortality (ENM), occurring within the first seven days, and late neonatal mortality (LNM), occurring between seven and 28 days of life. According to the World Health Organization (WHO), there were approximately 2.6 million neonatal deaths globally in 2016, accounting for nearly 46% of all under-five child deaths. Despite improvements in neonatal survival over recent decades, the reporting of neonatal deaths remains incomplete, with up to 62% of deaths unreported particularly in African regions, complicating efforts to accurately track and address this issue.

Globally, the neonatal mortality rate (NMR) has seen a substantial decline of 51% between 1990 and 2017. However, this progress is uneven; sub-Saharan Africa and South Asia report the highest NMRs, with rates over nine times those of high-income countries. Together, these regions represent about 79% of global neonatal deaths, with South Asia alone contributing to 38%, and East and South Africa accounting for approximately 18% of these deaths. Ethiopia is among the six countries responsible for half of the global under-five mortality, and it ranks among the top ten countries with the highest neonatal mortality figures, reporting an estimated 122,000 neonatal deaths annually [8–10]. This significant burden stresses the urgent need for focused intervention and research in the Ethiopian context.

The causes of neonatal mortality vary across the neonatal period. Prematurity has been identified as the primary cause of death during the early neonatal period, reflecting challenges related to lung immaturity and associated complications. Birth asphyxia predominates in the late neonatal period, often resulting from complications during labor and delivery. Respiratory distress syndrome (RDS) is also a common and critical contributor to neonatal deaths, often complicating premature birth and contributing to high mortality in neonatal intensive care units.

Additional significant contributors include birth injuries, neonatal infections, and hyperthermia, which adversely impact both early and late neonatal survival [14–16].

Numerous maternal and perinatal risk factors compound the risk of neonatal death. Maternal age extremes, high parity, short interpregnancy intervals, multiple pregnancies, maternal health complications during pregnancy, malpresentation of the fetus, delivery complications, and infant sex have all been linked to increased neonatal mortality risk. Understanding these factors is crucial for preventive strategies and targeted care.

In Ethiopia, the government has implemented several health sector transformation programs that improved maternal and newborn healthcare access, resulting in increased institutional deliveries and enhanced antenatal and postnatal care coverage. Programs focused on emergency obstetric and newborn care have further contributed to reducing maternal and under-five mortality, though neonatal mortality reduction has been comparatively slower, underscoring persistent gaps in neonatal health interventions [22–24].

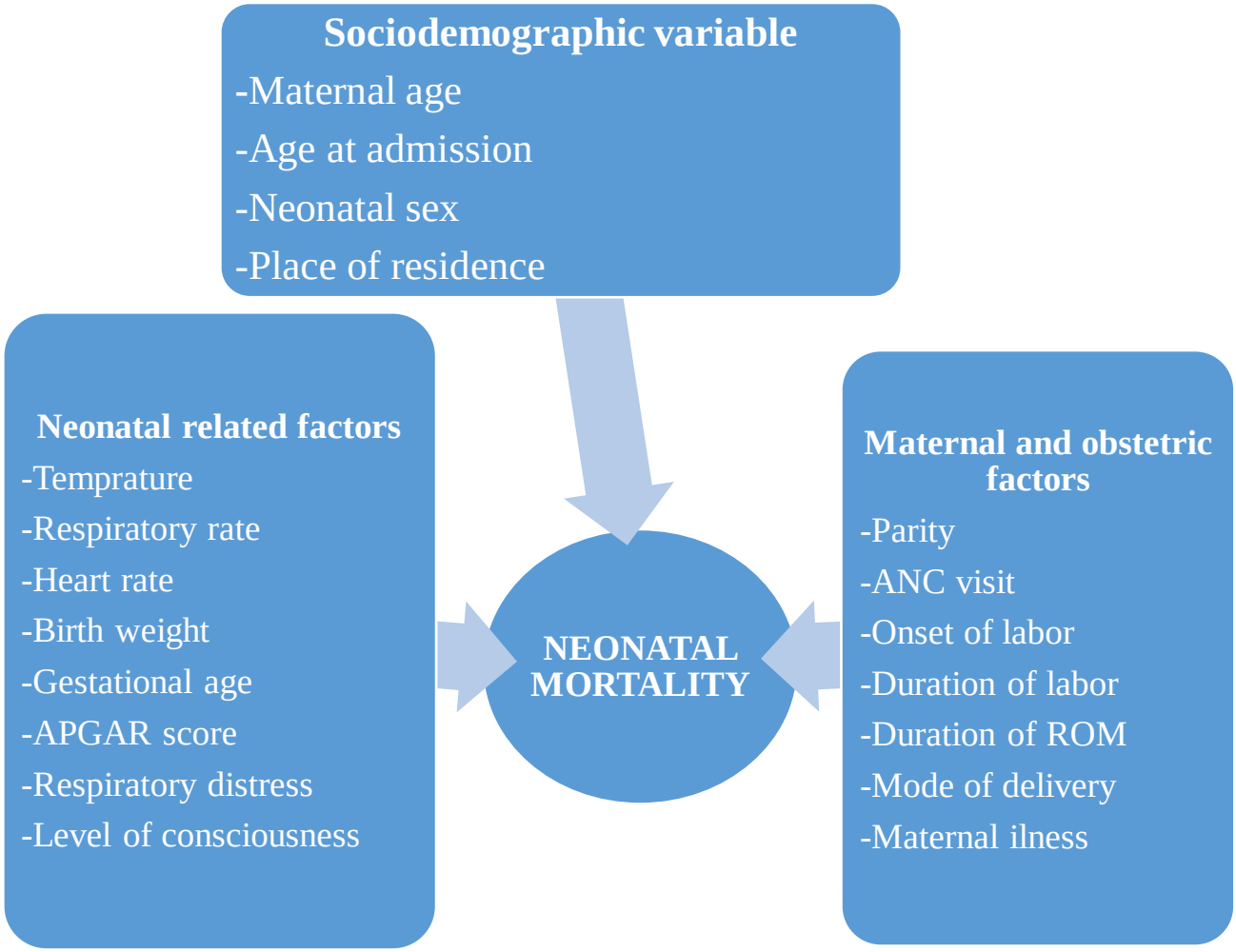
A promising strategy to improve neonatal outcomes involves the development of clinical prediction models which utilize combinations of risk factors to estimate the probability of neonatal mortality. These models facilitate early identification of high-risk neonates, enabling personalized clinical decisions and timely interventions within neonatal intensive care settings [25–27]. While such prognostic tools have been developed and validated in some low- and middle-income countries, including parts of South Asia, their application in Ethiopia remains limited.

This gap highlights the critical need for context-specific prediction models to enhance neonatal mortality risk stratification and improve resource allocation in Ethiopian healthcare facilities.

In conclusion, the high burden of neonatal mortality, especially in Ethiopia, driven by prematurity, birth asphyxia, and infections along with a constellation of maternal and perinatal risk factors, necessitates refined research and intervention (37, 38). Development and validation of neonatal mortality prediction models tailored to local contexts could provide invaluable support for clinical and policy-level decision-making aimed at reducing neonatal deaths.

3. Conceptual Framework

The framework considers how neonatal demographic characteristics (e.g., gestational age, birthweight), clinical features (e.g., respiratory distress, consciousness), and laboratory findings (e.g., sepsis markers) interact to influence neonatal survival. The proposed prognostic score integrates these predictors to estimate mortality risk.



4 Objectives

4.1 General Objective

To develop and internally validate a clinical risk score model that predicts the likelihood of neonatal mortality among newborns admitted to neonatal intensive care units (NICUs) at TASH, Addis Abeba.

4.2 Specific Objectives

To identify socio-demographic and clinical factors that are significantly associated with neonatal mortality among NICU admissions within the study period.

To develop a multivariable predictive model using the identified predictors to estimate the risk of neonatal mortality.
To construct a risk-scoring system derived from the regression model coefficients for use as a bedside clinical tool.

5 Methods and Materials

5.1 Study Area and Setting

The study will be conducted at the Neonatal Intensive Care Unit of TASH, the largest referral hospital in Ethiopia, located in Addis Ababa. Tikur Anbesa Specialized Hospital, established in 1974, is the largest tertiary hospital in the country. The hospital is administered by Addis Ababa University and is the largest and oldest teaching hospital. Tikur anbessa specialized hospital offers diagnosis and treatment for approximately 400,000 patients a year. Under the department of pediatrics and child health the NICU provides care for the sick newborns from all over the country. The NICU has 60 Beds. Currently there is 2 neonatologist, and 1 pediatrician. The NICU provide services for more than 150 neonates every month.

The study was also conducted at the Neonatal Intensive Care Unit (NICU) of Gandhi Memorial Hospital, a public hospital located in Addis Ababa. Established in 1959, the hospital operates under the Addis Ababa City Administration Health Bureau and primarily provides comprehensive maternal, newborn, and child health services. It serves as an important referral center for obstetric and neonatal cases within Addis Ababa and neighboring regions.

Gandhi Memorial Hospital has a high annual delivery volume, with approximately 14,000–15,000 births per year, including a considerable proportion of preterm and low-

birth-weight neonates. The hospital's NICU has approximately 44 beds and is equipped to provide specialized care for critically ill and high-risk newborns.

The NICU is staffed by pediatricians, residents, trained neonatal nurses, and midwives experienced in the management of critically ill newborns. On average, the unit admits a substantial number of neonates each month, reflecting its significant contribution to neonatal care services in Addis Ababa.

5.2 Study Design and Study Period

This study will be conducted using a hospital -based retrospective case-control study, from March 2025 – January 2026 G.C.

5.3 Source Population

All neonates admitted to TASH and GMH NICU during the study period.

5.4 Study Population

Cases: neonates who died during NICU admission.

Controls: neonates who survived

5.5Sample size and Sampling methods

Ideally, prognostic studies require several hundred outcome events.

There are no straightforward methods for sample size calculation for prognostic studies. Various studies have suggested that for each candidate predictor studied at least 10 events are required.

Hence, as the rule of thumb of at least 10 events per candidate variable for logistic regression prediction models was used to estimate the sample size in line with by Hosmer and Lemshow recommendation (44).
A consecutive sampling technique will be applied to select all eligible neonatal deaths (cases) during the study period, while systematic random sampling will be used to select the controls (neonates discharged alive). The sample size will be adjusted for incomplete records and potential non-response.

For development of the prediction model, we used the events-per-variable (EPV) rule. With 19 candidate predictors and a conservative EPV of 10 events per predictor, we require 190 outcome events (neonatal deaths) for stable model estimation ($19 \times 10 = 190$). Using a 2:1 control: case ratio, this corresponds to 380 controls, yielding a total sample size of 570 participants (190 cases and 380 controls).

5.6 Inclusion and exclusion criteria

5.61 Inclusion Criteria:

All neonates admitted to the NICU during the study period.

5.62 Exclusion Criteria:

Neonates with life threating congenital anomalies during neonatal period (46) or those who died before admission.

Neonates with incomplete or missing essential clinical data.

Neonates referred after partial management from another institution without baseline admission data.

5.7 Data collection and measurements

Data will be collected using a structured and pretested data abstraction questionnaire developed after reviewing relevant literature and neonatal care guidelines. Data collectors will extract data from medical records, admission/discharge logs, and registers, under close supervision by the principal investigator.

The dataset will include variables required for calculating neonatal mortality prediction scores, such as Neonatal, maternal, prenatal, intrapartum variables and therapeutic interventions administered during hospitalization. Additional information on neonatal outcomes, including survival status and time to death, will also be recorded.

5.8 Data handling

Collected data will be checked daily for completeness and consistency by the investigator. After verification, data will be entered into excel and exported to SPSS for analysis. The hard copies will be converted into soft copies, stored on hard drive and will be ready for analysis and back up copy will be stored on separate drive.

5.9 Study variables

Dependent variable-The primary outcome is neonatal mortality, defined as the death of a newborn occurring within the first 28 days of life during NICU admission. Outcome status will be confirmed through hospital discharge records and patient charts.

Independent variables

Sociodemographic factors include maternal age, residence, age of neonate at admission, and sex of the neonate.

Antepartum and maternal-related factors Pregnancy status, gravidity, parity, ANC visit, illness during pregnancy, history of adverse outcome, duration of pregnancy, syphilis status, and HIV status.

Neonatal factors Apgar score, breastfeeding, birth weight (BW), newborn resuscitation, initiation of breastfeeding, and admission diagnoses such as respiratory distress, perinatal asphyxia (PNA) (the failure of the neonate to initiate and sustain breathing) (30), sepsis, congenital malformation, hyaline membrane disease (RDS), jaundice, hypothermia, prematurity, and meconium aspirated syndrome. Initial vital signs upon NICU admission.

Intrapartum factors Mode of delivery, place of delivery, presence of meconium, and complications during delivery.

5.10 Data Quality Assurance

Primary investigator will check collected data completeness and it will be coded. A pilot test will be conducted on 5% of the sample to ensure tool clarity and validity. Daily supervision will be carried out to check for completeness and consistency. Data will be double-entered and cross-checked before analysis. Standard operational definitions will be applied throughout the study.

5.11 Data analysis

Data will be analyzed using **SPSS software**. Descriptive statistics will summarize sociodemographic, maternal, and clinical characteristics of cases and controls using frequencies, percentages, means, and standard deviations.

Bivariable logistic regression will be performed to identify potential predictors of neonatal mortality. Variables with a p-value < 0.25 will be selected for multivariable analysis.

A multivariable logistic regression model will be fitted to determine independent predictors of neonatal mortality. Adjusted Odds Ratios (AOR) with 95% Confidence Intervals (CI) will be reported, and significance will be declared at $p< 0.05$.

After obtaining the final model, its predictive performance will be assessed using two key metrics:

1. Discrimination: The model's ability to differentiate between neonates who died and those who survived will be evaluated using the Receiver Operating Characteristic (ROC) curve and the Area Under the Curve (AUC). AUC values of 0.7–0.8 indicate acceptable discrimination, 0.8–0.9 good discrimination, and > 0.9 excellent discrimination.
2. Calibration: The Hosmer–Lem show goodness-of-fit test will be used to compare observed vs. predicted mortality (44). A calibration plot (observed vs. predicted probabilities across deciles of risk) will also be generated. Non-significant Hosmer–Lem show test ($p > 0.05$) and alignment of points along the 45° line will indicate good calibration.

5.12 Construction of the Risk Prediction Score

Once the final multivariable logistic regression model is established, a clinical risk score will be derived as follows:
1. Extract regression coefficients (β values) of each independent predictor from the final logistic regression model.
2. Identify the smallest absolute β coefficient and divide each coefficient by this smallest β to standardize the relative contribution of each predictor.
3. Round the standardized coefficients to the nearest whole number to assign integer weights (points) for each predictor variable.
4. Compute an individual risk score for each neonate by summing the points corresponding to the predictors present.
5. Determine risk categories (e.g., low, moderate, high risk) using percentile-based cut-offs or by analyzing sensitivity/specificity balance from the ROC curve.

5.13 Internal Validation of the Risk Model

Internal validation will be performed to assess model stability and optimism:
Based on Split-Sample Validation, the dataset will be randomly split into a development set (70%) and a validation set (30%) for validation used to evaluate the model's predictive performance (45). This approach allows assessment of the model's discrimination and calibration on data not used in its development, providing an internal check against overfitting and helping to estimate how well the model may perform on similar future populations.

6 Ethical considerations

Ethical clearance to conduct this study will be obtained from the Pediatrics and Child Health Department's Research and Publications Committee of the School of Medicine, College of Health Sciences, Addis Ababa University. Confidentiality will be fully maintained during Data Collection and further analysis and dissemination of results.

7 Dissemination of finding

The finding of the study will be presented on the research defense day and a formal report will be submitted to the Department of Pediatrics and Child Health with both soft and hard copy. For the publication purpose, the abstract of this thesis will be submitted to national or international Peer reviewed publishers.

8 Operational definitions

Neonate: A newborn who is less than 28 days old at the time of admission to the Neonatal Intensive Care Unit (NICU).

Mortality: The occurrence of death within the neonatal period, defined as the first 28 days of life for this study.

Cases were defined as newborns who died in the NICU, and **controls** were defined as newborns who survived in neonatal period during NICU admission.

Risk Score: A numerical score derived from a set of maternal and neonatal variables that predicts the probability of neonatal mortality. The score is calculated based on regression coefficients from a logistic regression model.

Admission Weight: The weight of the neonate measured within the first hours after birth, categorized as low birth weight (<2500 grams), very low birth weight (<1500 grams), and normal birth weight (≥2500 grams).

Apgar Score: A scoring system used to assess the health of a newborn immediately after birth, based on five criteria: appearance, pulse, grimace response, activity, and respiration, scored from 0 to 10.

Life-threatening congenital anomalies are structural or functional abnormalities present at birth that are likely to result in death or severe morbidity in the neonatal period (first 28 days of life) without prompt medical or surgical intervention (46).

9. RESULTS

9.1 Study Population

A total of 570 neonates were included in this case–control study conducted at the NICU of TASH. Of these, 381 (66.8%) were controls (survived neonates) and 189 (33.2%) were cases (neonatal deaths), giving a case-to-control ratio of approximately 1:2.

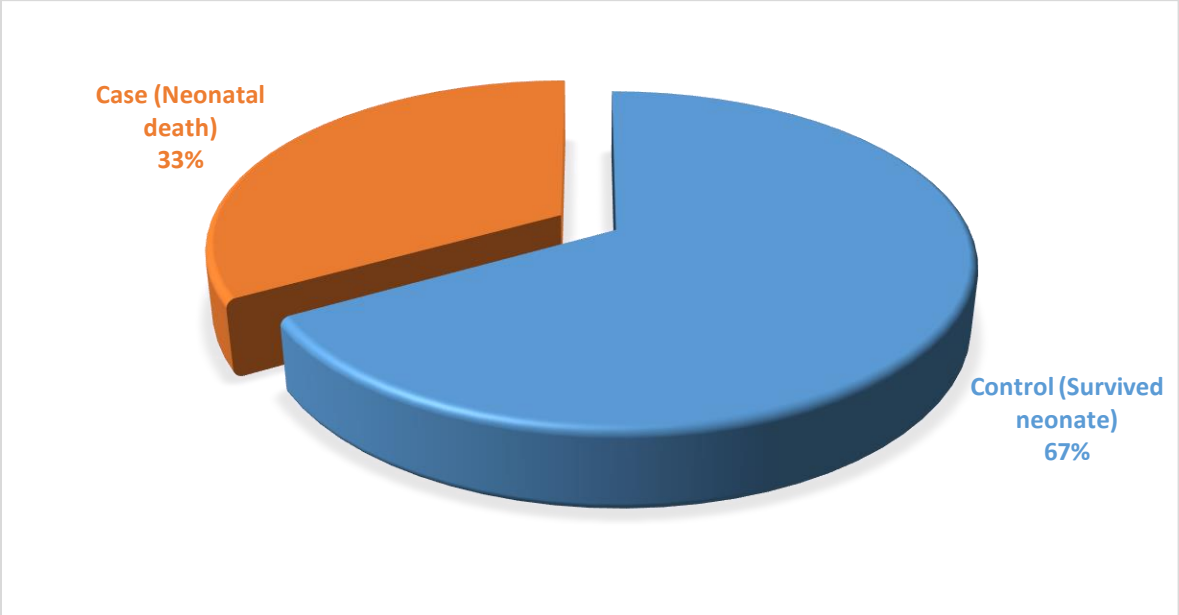


Fig 2 Distribution of Study Participants by Outcome Status (N = 570) at TASH and GMH, Addis Abeba

9.2 Socio-Demographic Characteristics

In our study, nearly half of the cases (89; 47.1%) were born to mothers aged ≤25 years, compared to 102 (26.8%) of controls. Mothers aged 26–34 years accounted for 91

(48.1%) of cases and 249 (65.4%) of controls, while those aged ≥35 years comprised 9 (4.8%) of cases and 30 (7.9%) of controls ($p < 0.001$). Regarding residence, 183 (96.8%) of cases and 356 (93.4%) of controls were urban residents, whereas 6 (3.2%) of cases and 25 (6.6%) of controls were rural residents ($p = 0.093$).

For maternal educational status, 106 (56.1%) of cases and 177 (46.5%) of controls had primary education, 10 (5.3%) of cases and 39 (10.2%) of controls had no formal education, and the remainder had secondary or higher education ($p = 0.084$). Regarding maternal occupation, 102 (54.0%) of cases and 186 (48.8%) of controls were housewives, while government-employed mothers were 17 (9.0%) of cases and 76 (19.9%) of controls ($p = 0.004$).

In terms of parity, primiparous mothers comprised 99 (52.4%) of cases and 158 (41.5%) of controls, and multiparous mothers were 90 (47.6%) of cases and 223 (58.5%) of controls ($p = 0.014$). For father's educational status, higher education was reported in 60 (31.7%) of cases and 134 (35.2%) of controls, secondary education in 71 (37.6%) of cases and 127 (33.3%) of controls, primary education in 54 (28.6%) of cases and 111 (29.1%) of controls, and no formal education in 4 (2.1%) of cases and 9 (2.4%) of controls ($p = 0.769$).Table 2: Socio-Demographic Characteristics and Neonatal Mortality (N = 570)

Table 1: Socio-Demographic Characteristics by Study Group (N = 570) at TASH, Addis Abeba

Variable	Category	Controls n (%)	Cases n (%)	COR (95% CI)	p-value
Maternal Age	≤25 years	102 (26.8%)	89 (47.1%)	1	—
	26–34 years	249 (65.4%)	91 (48.1%)	0.42 (0.29–0.61)	<0.001
	≥35 years	30 (7.9%)	9 (4.8%)	0.34 (0.16–0.76)	0.009
Residence	Urban	356 (93.4%)	183 (96.8%)	1	—
	Rural	25 (6.6%)	6 (3.2%)	0.47 (0.19–1.16)	0.100
Maternal Education	No formal education	39 (10.2%)	10 (5.3%)	1	—
	Primary	177 (46.5%)	106 (56.1%)	2.34 (1.12–4.87)	0.024
	Secondary	128 (33.6%)	56 (29.6%)	1.71 (0.80–3.66)	0.170
	Higher	37 (9.7%)	17 (9.0%)	1.79 (0.73–4.41)	0.205
Occupation	Housewife	186 (48.8%)	102 (54.0%)	1	—
	Government employed	76 (19.9%)	17 (9.0%)	0.41 (0.23–0.73)	0.002
	Private/Self-employed	116 (30.4%)	70 (37.0%)	1.10 (0.75–1.61)	0.624
	Other*	3 (0.8%)	0 (0.0%)	—	—
Parity	Primipara	158 (41.5%)	99 (52.4%)	1	—
	Multipara	223 (58.5%)	90 (47.6%)	0.64 (0.45–0.92)	0.014
Father Education	No formal education	9 (2.4%)	4 (2.1%)	1	—
	Primary	111 (29.1%)	54 (28.6%)	1.10 (0.32–3.71)	0.885
	Secondary	127 (33.3%)	71 (37.6%)	1.26 (0.37–4.23)	0.711

	Higher	134 (35.2%)	60 (31.7%)	1.01 (0.30–3.40)	0.990

9.3 Maternal & Obstetric Factors

Almost all mothers had antenatal care (ANC) visits, with 378 (99.2%) of controls and 188 (99.5%) of cases attending at least once, while 3 (0.8%) of controls and 1 (0.5%) of cases had no ANC visit (p = 0.728). Regarding place of delivery, 241 (63.3%) of controls and 133 (70.4%) of cases delivered in hospitals, 139 (36.5%) of controls and 53 (28.0%) of cases delivered in health centers, and home deliveries were 1 (0.3%) for controls and 3 (1.6%) for cases (p = 0.033). For mode of delivery, spontaneous vaginal delivery (SVD) occurred in 198 (52.0%) of controls and 85 (45.0%) of cases, cesarean section in 161 (42.3%) of controls and 91 (48.1%) of cases, and instrumental delivery in 22 (5.8%) of controls and 13 (6.9%) of cases (p = 0.288).

Regarding duration of labor, 208 (54.6%) of controls and 111 (58.7%) of cases had labor lasting ≥12 hours, while 173 (45.4%) of controls and 78 (41.3%) of cases had labor <12 hours (p = 0.349). Premature rupture of membranes (PROM) occurred in 108 (28.3%) of controls and 48 (25.4%) of cases, with 273 (71.7%) of controls and 141 (74.6%) of cases having no PROM (p = 0.457). Preeclampsia/eclampsia was reported in 31 (8.1%) of controls and 45 (23.8%) of cases, with 350 (91.9%) of controls and 144 (76.2%) of cases having no condition (p < 0.001).

Previous uterine scar was rare, observed in 2 (0.5%) of controls and 1 (0.5%) of cases (p = 0.995). Antepartum hemorrhage occurred in 35 (9.2%) of controls and 34 (18.0%) of cases, with 346 (90.8%) of controls and 155 (82.0%) of cases having no hemorrhage (p = 0.002). Chorioamnionitis was reported in 11 (2.9%) of controls and 5 (2.6%) of cases, with 370 (97.1%) of controls and 184 (97.4%) of cases without it (p = 0.869). Multiple gestation occurred in 16 (4.3%) of controls and 31 (17.1%) of cases, and singleton pregnancy in 358 (95.7%) of controls and 150 (82.9%) of cases (p < 0.001).

Cephalopelvic disproportion (CPD) was reported in 1 (0.5%) of cases and none of the controls (p = 0.155). Gestational diabetes mellitus occurred in 1 (0.3%) of controls and none of the cases (p = 0.481). Meconium aspiration syndrome (MAS) was present in 21

(5.5%) of controls and 23 (12.2%) of cases (p = 0.005). Malpresentation was observed in 2 (0.5%) of controls and 2 (1.1%) of cases (p = 0.473). There were no breech presentations in either group. Regarding maternal HIV status, 377 (99.0%) of controls and 184 (97.4%) of cases were HIV negative, 4 (1.0%) of controls and 3 (1.6%) of cases were positive, and 0 controls and 2 (1.1%) of cases had unknown status (p = 0.113)

Table 2 : Maternal and Perinatal Factors and Neonatal Mortality at TASH, Addis Abeba

Variable	**Category**	**Controls (n, %)**	**Cases (n, %)**	**COR (95% CI)**	**p-value**
ANC Visit	Yes	378 (99.2)	188 (99.5)	0.67 (0.07–6.49)	0.73
	No	3 (0.8)	1 (0.5)	1	
Place of Delivery	Hospital	241 (63.3)	133 (70.4)	1	
	Health Center	139 (36.5)	53 (28.0)	0.69 (0.47–1.01)	0.057
	Home	1 (0.3)	3 (1.6)	5.44 (0.56–52.78)	0.144
Mode of Delivery	SVD	198 (52.0)	85 (45.0)	1	
	Instrumental	22 (5.8)	13 (6.9)	1.38 (0.66–2.86)	0.392
	Cesarean	161 (42.3)	91 (48.1)	1.32 (0.92–1.89)	0.136
Duration of Labor	≥12 hours	208 (54.6)	111 (58.7)	1.18 (0.83–1.68)	0.349
	<12 hours	173 (45.4)	78 (41.3)	1	
PROM	Yes	108 (28.3)	48 (25.4)	0.86 (0.58–1.28)	0.457
	No	273 (71.7)	141 (74.6)	1	
Preeclampsia/Eclampsia	Yes	31 (8.1)	45 (23.8)	**3.53 (2.15–5.80)**	**<0.001**
	No	350 (91.9)	144 (76.2)	1	
Previous Scar	Yes	2 (0.5)	1 (0.5)	1.01 (0.09–11.19)	0.995
	No	379 (99.5)	188 (99.5)	1	
Antepartum Hemorrhage	Yes	35 (9.2)	34 (18.0)	2.17 (1.30–3.61)	0.003
	No	346 (90.8)	155 (82.0)	1	
Chorioamnionitis	Yes	11 (2.9)	5 (2.6)	0.91 (0.31–2.67)	0.869
	No	370 (97.1)	184 (97.4)	1	
Multiple Gestation	Yes	16 (4.3)	31 (17.1)	**4.62 (2.46–8.71)**	**<0.001**
	No	358 (95.7)	150 (82.9)	1	
CPD	Yes	0 (0.0)	1 (0.5)	—	
	No	381 (100)	188 (99.5)		
Gestational DM	Yes	1 (0.3)	0 (0.0)	—	
	No	380 (99.7)	189 (100)	1	

MAS	Yes	21 (5.5)	23 (12.2)	2.38 (1.28–4.41)	0.006
	No	360 (94.5)	166 (87.8)	1	
Malpresentation	Yes	2 (0.5)	2 (1.1)	2.03 (0.28–14.50)	0.482
	No	379 (99.5)	187 (98.9)	1	
Breech	—	0 (0)	0 (0)	—	—
HIV Status	Positive	4 (1.0)	3 (1.6)	1.54 (0.34–6.94)	0.576
	Negative	377 (99.0)	184 (97.4)	1	
	Unknown	0 (0)	2 (1.1)	—	—

9.4 Neonatal Characteristics

In this study, of the 570 neonates, 293 (51.4%) were male and 277 (48.6%) were female, with 205 (53.8%) of controls and 88 (46.6%) of cases being male, and 176 (46.2%) of controls and 101 (53.4%) of cases being female ($p = 0.103$). Regarding gestational age, the majority of controls, 244 (64.0%), were born at ≥37 weeks, compared to 56 (29.6%) of cases. Preterm births of 32–36 weeks included 111 (29.1%) of controls and 34 (18.0%) of cases, 28–32 weeks included 26 (6.8%) of controls and 87 (46.0%) of cases, while <28 weeks were observed only among 12 (6.3%) cases ($p < 0.001$).

Birth weight distribution showed that 213 (55.9%) of controls and 47 (24.9%) of cases weighed ≥2500 gm, 131 (34.4%) of controls and 39 (20.6%) of cases weighed 1500–2499 gm, 28 (7.3%) of controls and 88 (46.6%) of cases weighed 1000–1499 gm, 2 (0.5%) of controls and 13 (6.9%) of cases weighed <1000 gm, and 7 (1.8%) of controls and 2 (1.1%) of cases weighed >4000 gm ($p < 0.001$).

APGAR scores at 1 minute revealed that most controls, 348 (91.3%), scored 7–10, compared to 110 (58.2%) of cases. Scores of 4–6 were seen in 29 (7.6%) of controls and 71 (37.6%) of cases, while scores of 0–3 were observed in 4 (1.0%) of controls and 8 (4.2%) of cases ($p < 0.001$). At 5 minutes, 371 (97.4%) of controls and 158 (83.6%) of cases scored 7–10, 9 (2.4%) of controls and 30 (15.9%) of cases scored 4–6, and 1 (0.3%) of controls and 1 (0.5%) of cases scored 0–3 ($p < 0.001$).

Regarding resuscitation at birth, 329 (86.4%) of controls and 111 (58.7%) of cases required no resuscitation, 31 (8.1%) of controls and 25 (13.2%) of cases required suction only, while 21 (5.5%) of controls and 53 (28.0%) of cases required bag and mask ($p <$

0.001). For size for gestational age, 329 (86.4%) of controls and 169 (89.4%) of cases were appropriate for gestational age, 41 (10.8%) of controls and 17 (9.0%) of cases were small for gestational age, and 11 (2.9%) of controls and 3 (1.6%) of cases were large for gestational age (p = 0.498).

Table 3: Neonatal Factors at TASH, Addis Abeba

Variable	Category	Control (n=381)	Case (n=189)	COR (95% CI)	p-value
Sex of Neonate	Male	205 (53.8%)	88 (46.6%)	1	0.103
	Female	176 (46.2%)	101 (53.4%)	0.75 (0.53–1.06)	
Gestational Age	≥37 wks.	244 (64.0%)	56 (29.6%)	1	<0.001
	32–36 wks.	111 (29.1%)	34 (18.0%)	1.34 (0.83–2.16)	
	28–32 wks.	26 (6.8%)	87 (46.0%)	14.58 (8.62–24.66)	
	<28 wks.	0 (0.0%)	12 (6.3%)	—	
Birth Weight	≥2500 gm	213 (55.9%)	47 (24.9%)	1	<0.001
	1500–2499 gm	131 (34.4%)	39 (20.6%)	1.35 (0.84–2.17)	
	1000–1499 gm	28 (7.3%)	88 (46.6%)	14.24 (8.39–24.19)	
	<1000 gm	2 (0.5%)	13 (6.9%)	1.30 (0.26–6.43)	
	>4000 gm	7 (1.8%)	2 (1.1%)	—	
APGAR 1 min	0–3	4 (1.0%)	8 (4.2%)	1	<0.001
	4–6	29 (7.6%)	71 (37.6%)	1.22 (0.34–4.38)	
	7–10	348 (91.3%)	110 (58.2%)	0.16 (0.05–0.54)	
APGAR 5 min	0–3	1 (0.3%)	1 (0.5%)	1	<0.001
	4–6	9 (2.4%)	30 (15.9%)	3.33 (0.19–58.80)	
	7–10	371 (97.4%)	158 (83.6%)	0.43 (0.03–6.85)	
Resuscitation at Birth	None	329 (86.4%)	111 (58.7%)	1	<0.001
	Suction only	31 (8.1%)	25 (13.2%)	2.39 (1.35–4.22)	
	Bag & Mask	21 (5.5%)	53 (28.0%)	7.48 (4.32–12.96)	
Size for Gestational	AGA	329 (86.4%)	169 (89.4%)	1	0.498
	SGA	41 (10.8%)	17 (9.0%)	0.81 (0.45–1.46)	

Age	LGA	11 (2.9%)	3 (1.6%)	0.53 (0.15–1.93)	

9.5 Admission Clinical Parameters

Regarding temperature, 320 (84.0%) of controls and 103 (54.5%) of cases had normal temperature, while 61 (16.0%) of controls and 86 (45.5%) of cases had abnormal temperature ($p < 0.001$).

For heart rate, 352 (92.4%) of controls and 166 (87.8%) of cases had a normal heart rate, 28 (7.3%) of controls and 21 (11.1%) of cases had tachycardia, and 1 (0.3%) of controls and 2 (1.1%) of cases had bradycardia ($p = 0.143$).

Regarding respiratory rate, 177 (46.5%) of controls and 39 (20.6%) of cases had a normal respiratory rate, 199 (52.2%) of controls and 140 (74.1%) of cases had a high respiratory rate, and 5 (1.3%) of controls and 10 (5.3%) of cases had a low respiratory rate ($p < 0.001$).

For respiratory distress, 105 (27.6%) of controls and 5 (2.6%) of cases had no distress, 160 (42.0%) of controls and 35 (18.5%) of cases had mild distress, 95 (24.9%) of controls and 78 (41.3%) of cases had moderate distress, and 21 (5.5%) of controls and 71 (37.6%) of cases had severe distress ($p < 0.001$).

Regarding level of consciousness, 344 (90.3%) of controls and 107 (56.6%) of cases were alert, 24 (6.3%) of controls and 32 (16.9%) of cases were irritable, 13 (3.4%) of controls and 45 (23.8%) of cases were lethargic, and 0 (0.0%) of controls and 5 (2.6%) of cases were comatose ($p < 0.001$).

For birth asphyxia, 353 (92.7%) of controls and 122 (64.6%) of cases had no asphyxia, while 28 (7.3%) of controls and 67 (35.4%) of cases had birth asphyxia ($p < 0.001$).

Regarding suspected sepsis, 56 (14.7%) of controls and 8 (4.2%) of cases had no sepsis, while 325 (85.3%) of controls and 181 (95.8%) of cases had suspected sepsis ($p < 0.001$).

For respiratory distress syndrome (RDS), 344 (90.3%) of controls and 101 (53.4%) of cases had no RDS, while 37 (9.7%) of controls and 88 (46.6%) of cases had RDS ($p < 0.001$).

Regarding feeding difficulty, 233 (61.2%) of controls and 80 (42.3%) of cases had no difficulty, while 148 (38.8%) of controls and 109 (57.7%) of cases had feeding difficulty ($p < 0.001$).

For congenital anomaly (non-life-threatening), 364 (95.5%) of controls and 175 (92.6%) of cases had no anomaly, while 17 (4.5%) of controls and 14 (7.4%) of cases had anomaly ($p = 0.148$).

Regarding meconium aspiration syndrome (MAS), 360 (94.5%) of controls and 166 (87.8%) of cases had no MAS, while 21 (5.5%) of controls and 23 (12.2%) of cases had MAS ($p = 0.006$).

For jaundice, 309 (81.1%) of controls and 183 (96.8%) of cases had no jaundice, while 72 (18.9%) of controls and 6 (3.2%) of cases had jaundice ($p < 0.001$).

Regarding seizures, 374 (98.2%) of controls and 178 (94.2%) of cases had no seizures, while 7 (1.8%) of controls and 11 (5.8%) of cases had seizures ($p = 0.015$)

Table 4: Clinical Status at Admission at TASH, Addis Abeba

Variable	Category	Control (n=381)	Case (n=189)	COR (95% CI)	p-value
Temperature (°C)	<36	42 (11.0%)	70 (37.0%)	1	
	32–36	1 (0.3%)	3 (1.6%)	1.80 (0.18–17.87)	0.616
	36–36.4	138 (36.2%)	68 (36.0%)	0.41 (0.18–0.92)	0.03
	36.5–37.5	181 (47.5%)	35 (18.5%)	0.12 (0.07–0.20)	<0.001
	>37.5	19 (5.0%)	13 (6.9%)	0.30 (0.18–0.48)	<0.001
Heart rate (bpm)	<100	1 (0.3%)	2 (1.1%)	1	
	100–160	352 (92.4%)	166 (87.8%)	0.24 (0.02–2.62)	0.24
	>160	28 (7.3%)	21 (11.1%)	0.38 (0.03–4.42)	0.436
Respiratory rate (brpm)	<30	5 (1.3%)	10 (5.3%)	1	<0.001
	30–60	177 (46.5%)	39 (20.6%)	0.11 (0.04–0.34)	<0.001
	>60	199 (52.2%)	140 (74.1%)	0.35 (0.12–1.05)	0.061

Respiratory distress	None	105 (27.6%)	5 (2.6%)	1	
	Mild	160 (42.0%)	35 (18.5%)	4.59 (1.74–12.10)	0.002
	Moderate	95 (24.9%)	78 (41.3%)	17.24 (6.70–44.40)	<0.001
	Severe	21 (5.5%)	71 (37.6%)	71.00 (25.58–197.04)	<0.001
Level of consciousness	Alert	344 (90.3%)	107 (56.6%)	1	
	Comatose	0 (0.0%)	5 (2.6%)	5.19×10^{9}	0.999
	Irritable	24 (6.3%)	32 (16.9%)	4.29 (2.42–7.60)	<0.001
	Lethargic	13 (3.4%)	45 (23.8%)	11.13 (5.79–21.41)	<0.001
Birth asphyxia	No	353 (92.7%)	122 (64.6%)	1	
	Yes	28 (7.3%)	67 (35.4%)	6.92 (4.26–11.27)	<0.001
Suspected sepsis	No	56 (14.7%)	8 (4.2%)	1	
	Yes	325 (85.3%)	181 (95.8%)	3.90 (1.82–8.36)	<0.001
RDS	No	344 (90.3%)	101 (53.4%)	1	
	Yes	37 (9.7%)	88 (46.6%)	8.10 (5.20–12.62)	<0.001
Feeding difficulty	No	233 (61.2%)	80 (42.3%)	1	
	Yes	148 (38.8%)	109 (57.7%)	0.47 (0.33–0.67)	<0.001
Congenital anomaly (non-life-threatening)	No	364 (95.5%)	175 (92.6%)	1	
	Yes	17 (4.5%)	14 (7.4%)	1.71 (0.83–3.55)	0.148
MAS	No	360 (94.5%)	166 (87.8%)	1	
	Yes	21 (5.5%)	23 (12.2%)	2.38 (1.28–4.41)	0.006
Jaundice	No	309 (81.1%)	183 (96.8%)	1	
	Yes	72 (18.9%)	6 (3.2%)	0.14 (0.06–0.33)	<0.001
Seizure	No	374 (98.2%)	178 (94.2%)	1	
	Yes	7 (1.8%)	11 (5.8%)	3.30 (1.26–8.66)	0.015

9.6 Predictors of Neonatal Mortality

Multivariable logistic regression was performed to identify independent predictors of neonatal mortality. Variables with p-values <0.25 in the bivariable analysis were included in the model. After adjustment for potential confounders, meconium aspiration syndrome (MAS), gestational age, birth weight, and resuscitation at birth remained statistically significant predictors of neonatal death. Neonates with MAS had 4.1 times higher odds of mortality compared to those without MAS (AOR = 4.10; 95% CI: 1.61–10.40; p = 0.003). Preterm neonates born at 28–32 weeks of gestation had 5.4-fold higher odds of death compared to term neonates (AOR = 5.41; 95% CI: 1.57–18.66; p = 0.008). Birth weight between 1000–1499 g was associated with a 6.9-fold increased risk of neonatal

death (AOR = 6.94; 95% CI: 1.88–25.64; p = 0.004). Furthermore, neonates requiring bag-and-mask resuscitation at birth had a 4.8-fold higher likelihood of mortality compared to those who did not require resuscitation (AOR = 4.83; 95% CI: 1.50–15.54; p = 0.008). Other variables, including maternal age, residence, educational status, parity, sex of the neonate, APGAR score at 1 or 5 minutes, and size for gestational age, were not independently associated with neonatal mortality after adjusting for confounding factors.

The model demonstrated good fit and predictive performance, with a Nagelkerke R^2 of 0.53, indicating that 53% of the variability in neonatal mortality was explained by the model. The Hosmer–Lem show goodness-of-fit test was non-significant ($\chi^2 = 6.70$, df = 8, p = 0.570), suggesting that the model predictions were well-calibrated.

Table 5: Independent Predictors of Neonatal Mortality

Variable	Category	Adjusted Odds Ratio (AOR)	95% Confidence Interval	p-value
MAS	Yes	4.1	1.61 – 10.40	0.003
	No	1	–	–
Gestational Age	28–32 wks.	5.41	1.57 – 18.66	0.008
	≥37 wks.	1	–	–
Birth Weight	1000–1499 g	6.94	1.88 – 25.64	0.004
	≥2500 g	1	–	–
Resuscitation at birth	Bag & Mask	4.83	1.50 – 15.54	0.008
	None	1	–	–

9.7 Risk Score Construction

A neonatal mortality risk score was developed based on the β coefficients of the independent predictors from the multivariable logistic regression model. Each β coefficient was rounded to the nearest integer to assign a point value for each predictor.

Predictor	β coefficient	Score
MAS (Meconium Aspiration Syndrome)	1.410	1
Gestational Age 28–32 weeks	1.688	2
Birth Weight 1000–1499 g	1.937	2
Resuscitation at Birth – Bag & Mask	1.574	2

Total score range: 0–7 points.

Higher total scores indicate a higher predicted risk of neonatal mortality.

Based on the constructed neonatal mortality risk score (total range: 0–7 points), risk categories were developed to facilitate clinical interpretation and bedside application. The categorization was designed to stratify neonates into clinically meaningful groups according to their cumulative risk burden.

Since the total score ranges from 0 to 7 and includes four predictors with weighted contributions (1–2 points each), the following three-tier risk classification is proposed:

Total Score	Risk Category	Interpretation
0–2 points	Low Risk	Minimal predicted risk of neonatal mortality. Routine NICU monitoring and standard management are generally sufficient.
3–5 points	Moderate Risk	Intermediate predicted risk. Requires closer monitoring, early intervention, and prioritization for supportive care.
6–7 points	High Risk	High predicted risk of neonatal mortality. Requires intensive monitoring, aggressive management, and possible escalation of respiratory and supportive therapies.

10 Discussion

This study aimed to identify independent predictors of neonatal mortality among NICU admissions at Tikur Anbessa Specialized Hospital (TASH) and Ghandi memorial hospital (GMH), Addis Ababa, and to develop a simple prognostic risk score. The overall proportion of neonatal death in this case–control sample was 33.2%, reflecting the high burden of mortality among critically ill neonates admitted to tertiary-level NICUs in Ethiopia.

The final multivariable model identified four independent predictors of neonatal mortality: meconium aspiration syndrome (MAS), gestational age (28–32 weeks), low

birth weight (1000–1499 g), and the need for bag-and-mask resuscitation at birth. The model demonstrated good explanatory power (Nagelkerke $R^2 = 0.53$) and good calibration (Hosmer–Lemshows p = 0.570), indicating acceptable predictive performance.

These findings are largely consistent with previous Ethiopian studies, including the study conducted in Southern Ethiopia on "Development and validation of a risk score to predict neonatal mortality among NICU admissions" and the case–control study on "Derivation and validation of a prognostic score for neonatal mortality in Ethiopia," both of which highlighted prematurity, low birth weight, birth asphyxia, and respiratory conditions as key determinants of neonatal death.

Socio-Demographic and Maternal Factors

In the bivariable analysis, younger maternal age (≤25 years), primary maternal education, maternal occupation (housewife), and primiparity were associated with neonatal mortality. However, after adjusting for neonatal and clinical variables, these factors did not remain statistically significant.

This pattern suggests that socio-demographic factors may exert their effect indirectly through obstetric complications and adverse neonatal conditions. Similar findings were reported in the Southern Ethiopia NICU risk score study, where socio-demographic characteristics were not independent predictors after controlling for clinical variables. The case–control study on prognostic score derivation in Ethiopia also demonstrated that neonatal clinical status at admission outweighed background maternal characteristics in predicting mortality.

The lack of independent association in our study may also reflect the relatively homogenous urban population (over 90% urban residents) and the high antenatal care attendance rate (>99%), which could have reduced variability in access-related factors.

Maternal and Obstetric Factors

Several obstetric factors—preeclampsia/eclampsia, antepartum hemorrhage, multiple gestation, and MAS—were significantly associated with mortality in the bivariable analysis. However, only MAS remained significant in the adjusted model (AOR = 4.10; 95% CI: 1.61–10.40).

The strong association between MAS and neonatal death is biologically plausible. MAS can lead to severe respiratory distress, persistent pulmonary hypertension, hypoxia, and multi-organ dysfunction. Similar associations were reported in Ethiopian studies and other low-resource settings, where MAS substantially increased the odds of mortality among NICU admissions.

Although preeclampsia/eclampsia and multiple gestation were significant in crude analysis, their effects may have been mediated through prematurity and low birth weight, which were included in the multivariable model. This aligns with findings from previous Ethiopian prognostic score studies, where the inclusion of gestational age and birth weight attenuated the effects of maternal complications.

Neonatal Characteristics

Gestational age was a strong predictor of neonatal mortality. Neonates born at 28–32 weeks had more than five times higher odds of death compared to term neonates (AOR = 5.41; 95% CI: 1.57–18.66). This finding is consistent with global and national evidence demonstrating that prematurity is one of the leading causes of neonatal death.

The Southern Ethiopia risk score study similarly identified prematurity as a major component of their predictive model. In the Ethiopian case–control prognostic score study, gestational age was also retained as a key predictor in the final model. The vulnerability of preterm neonates is attributable to immature organ systems, particularly the lungs, brain, and immune system, which predispose them to respiratory distress syndrome (RDS), sepsis, hypothermia, and feeding difficulties.

Birth weight was another strong independent predictor. Neonates weighing 1000–1499 g had nearly seven times higher odds of death compared to those weighing ≥2500 g (AOR = 6.94; 95% CI: 1.88–25.64). Low birth weight often overlaps with prematurity, but it also independently reflects intrauterine growth restriction and nutritional compromise. The magnitude of association in this study is comparable to that reported in other Ethiopian NICU-based studies, reinforcing the critical importance of low birth weight as a prognostic marker.

Interestingly, APGAR scores at 1 and 5 minutes, although strongly associated in crude analysis, did not remain independent predictors after adjustment. This may be due to collinearity with resuscitation and gestational age, which better capture the severity of neonatal compromise at birth.

Admission Clinical Parameters

Clinical instability at admission—such as abnormal temperature, respiratory distress, altered level of consciousness, birth asphyxia, suspected sepsis, RDS, feeding difficulty, and seizures—was strongly associated with mortality in bivariable analysis.

However, in the multivariable model, the need for bag-and-mask resuscitation remained the key independent clinical predictor (AOR = 4.83; 95% CI: 1.50–15.54). The requirement for active resuscitation reflects significant perinatal compromise and possibly delayed or inadequate intrapartum care. Similar findings were observed in the Ethiopian prognostic score derivation study, where markers of birth asphyxia and resuscitation were strongly predictive of death.

The fact that resuscitation remained significant while APGAR did not suggest that objective interventions (such as bag-and-mask ventilation) may be more reliable indicators of severe neonatal compromise in low-resource settings.

Risk Score Development and Comparison

A simple neonatal mortality risk score was constructed using β coefficients from the final logistic regression model. Predictors included:

- MAS (1 point)
- Gestational age 28–32 weeks (2 points)
- Birth weight 1000–1499 g (2 points)
- Bag-and-mask resuscitation (2 points)

The total score ranged from 0 to 7 points, with higher scores indicating greater risk of mortality.

Compared with the Southern Ethiopia NICU risk score model, which also incorporated prematurity, low birth weight, and respiratory complications, the present score is similarly based on easily measurable clinical variables. However, our model explained 53% of the variability in mortality (Nagelkerke $R^2 = 0.53$), suggesting moderate-to-strong predictive performance.

The case–control prognostic score study done at UoG also emphasized the feasibility of using simple, bedside variables to stratify neonatal risk. The similarity of predictors across studies strengthens the external validity of these risk factors in the Ethiopian context.

The practical implication of this risk score is substantial. In resource limited NICUs, early identification of high-risk neonates allows prioritization of intensive monitoring, respiratory support, infection prevention strategies, and timely referral. Moreover, the use of a standardized risk score enhances clinical decision-making and may improve outcome tracking and quality improvement initiatives.

Strengths and Limitations

One major strength of this study is the relatively large sample size (N = 570) and the use of multivariable logistic regression to control for confounding factors. Additionally, the development of a locally derived risk score enhances contextual relevance.

However, several limitations should be acknowledged. First, the retrospective design may be subject to incomplete documentation and information bias. Second, as the study was conducted in a tertiary referral hospital, the findings may not be generalizable to primary-level facilities. Third, external validation of the risk score in other settings was not performed, limiting its immediate generalizability.

Despite these limitations, the study provides robust evidence on key predictors of neonatal mortality and contributes to the growing body of literature on neonatal prognostic modeling in Ethiopia.

Conclusion

This study identified meconium aspiration syndrome, prematurity, low birth weight, and the need for bag-and-mask resuscitation at birth as independent predictors of neonatal mortality among NICU admissions at TASH and GMH.

The developed neonatal mortality risk score, based on these predictors, demonstrated good calibration and moderate-to-strong predictive ability. The findings are consistent with previous Ethiopian studies on neonatal mortality risk score derivation and validation, reinforcing the central role of prematurity, low birth weight, and respiratory compromise in neonatal death.

Implementation of this simple, clinically applicable risk score in NICUs may facilitate early risk stratification, targeted management, and improved allocation of limited resources. Future prospective studies are recommended to externally validate and refine the score across different healthcare settings in Ethiopia.

11 Project work plan

Table 1

S.NO	Activities	Responsible person	Sep	Sep	Oct	Nov	Nov	Dec	Jan
1	Writing proposal	PI							
2	Submission Of 1st draft	PI							

5	Final proposal submission	PI							
6	Data collection	Data collector							
7	Analysis	PI							
8	Submission of 1st result	PI							
9	Submission of final result	PI							

12 Budget Breakdowns

Table 2

No	Category	Material	Units	Unit price(ETH birr)	Total(ETH birr)
1	Stationary and Supplies	Paper	10	250	2500
		Pen	10	15	150
		Binder	2	100	200
		Printer ink	1	4000	4000
		Subtotal	4350		
2	Personnel Expenses	Data collector	15	100	9275

3	Consultancy of Data Manager	Biostatistician(2)	4 days	2000/day	16000
4	Secretory work	Secretory	1500	2	3000
5	Cellphone cards	Cellphone cards	100	15	1500
6	Contingency	7500			
	Grand total	44,125			

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14 Annex:

TABLE 3 Life-Threatening Congenital Anomalies in the Neonatal Period (WHO classification)

A. Central Nervous System	B. Cardiovascular System	C. Respiratory and Thoracic
• Anencephaly – invariably fatal • Encephalocele (large, with brain tissue herniation) • Severe spina bifida with meningomyelocele • Severe hydrocephalus (causing brainstem compression)	• Hypoplastic left heart syndrome • Transposition of the great arteries (TGA) • Tetralogy of Fallot with pulmonary atresia • Critical coarctation of the aorta • Truncus arteriosus • Total anomalous pulmonary venous return (TAPVR) (obstructed type)	• Congenital diaphragmatic hernia (CDH) • Pulmonary hypoplasia • Congenital cystic adenomatoid malformation (large lesion causing respiratory distress)

D. Gastrointestinal Tract • Esophageal atresia with or without tracheoesophageal fistula • Duodenal or jejunal atresia • Intestinal obstruction (atresia/volvulus) • Omphalocele (large) • Gastroschisis • Imperforate anus without fistula	E. Genitourinary Tract • Bilateral renal agenesis (Potter sequence) • Severe obstructive uropathy (posterior urethral valves with renal failure)	F. Chromosomal/Syndromic • Trisomy 13 (Patau syndrome) • Trisomy 18 (Edwards syndrome) • Severe multiple congenital anomalies syndromes (e.g., complex VACTERL association)

Data collecting Questionnaire

Standard Questionnaire

Section A: Socio-demographic Characteristics

1. **Mother's Age**:
    - ☐< 25 years
    - ☐ 26–34 years
    - ☐ ≥ 35 years
2. **Mother's Residence**:
    - ☐ Urban
    - ☐ Rural
3. **Mother's Education Level**:
    - ☐ No formal education
    - ☐ Primary
    - ☐ Secondary

- ☐ Higher education

4. **Occupation of Mother**:
    - ☐ Housewife
    - ☐ Employed (specify: _____)
    - ☐ Self-employed
    - ☐ Other: _____

5. **Father's Education Level**:
    - ☐ No formal education
    - ☐ Primary
    - ☐ Secondary
    - ☐ Higher education
6. **Parity of Mother**:
    - ☐ Primipara (first birth)
    - ☐ Multipara (≥ 2 births)

Section B: Maternal & Obstetric Factors

7. **Antenatal Care (ANC) Attendance**:
    - ☐ Yes (Number of visits: ____)
    - ☐ No
8. **Mode of Delivery**:
    - ☐ Spontaneous vaginal delivery
    - ☐ Induced vaginal delivery
    - ☐ Cesarean section

9. **Duration of Labor**: _____ hours

10. **Rupture of Membranes**:
    - ☐ Intact
    - ☐ Ruptured (< 18 hours)
    - ☐ Prolonged rupture (≥ 18 hours)

11. **Maternal HIV Status**:
    - ☐ Positive
    - ☐ Negative
    - ☐ Unknown

12. **Other maternal conditions during pregnancy** (tick all that apply):
    - ☐ Hypertension / Preeclampsia
    - ☐ Diabetes mellitus
    - ☐ Infection (specify: _____)
    - ☐ None

Section C: Neonatal Characteristics

13. **Sex of Neonate**:
    - ☐ Male
    - ☐ Female

14. **Gestational Age** (by LMP or Ballard score):
    - ☐< 32 weeks (very preterm)
    - ☐ 32–36 weeks (preterm)

- ☐ ≥ 37 weeks (term)

15. **Birth Weight**:
    - ☐< 1500 g (very low birth weight)
    - ☐ 1500–2499 g (low birth weight)
    - ☐ ≥ 2500 g (normal)

16. **Size for Gestational Age**:
    - ☐ Small for gestational age (SGA)
    - ☐ Appropriate for gestational age (AGA)
    - ☐ Large for gestational age (LGA)
17. **Head Circumference**:
    - ☐ Microcephalic
    - ☐ Normocephalic
    - ☐ Macrocephalic
18. **Age at Admission**:
    - ☐ ≤ 1 hour
    - ☐> 1 hour
19. **APGAR Score**:
    - At 1 minute: ____
    - At 5 minutes: ____
20. **Resuscitation at Birth**:
    - ☐ None
    - ☐ Suction only

- ☐ Bag & Mask ventilation
- ☐ Intubation

Section D: Admission Clinical Parameters

21. **Vital Signs**:

- Temperature: ____ °C (☐<36.0 ☐ 36.0–36.4 ☐ 36.5–37.5 ☐>37.5)
- Heart Rate: ____ bpm (☐<100 ☐ 100–160 ☐>160)
- Respiratory Rate: ____ /min (☐<30 ☐ 30–60 ☐>60)

22. **Level of Consciousness**:

- ☐ Alert
- ☐ Irritable
- ☐ Lethargic
- ☐ Comatose

23. **Respiratory Distress**:

- ☐ None
- ☐ Mild (subcostal/intercostal retractions)
- ☐ Moderate (above + nasal flaring/grunting)
- ☐ Severe (above + perioral cyanosis)

24. **Other Clinical Problems at Admission** (tick all that apply):

- ☐ Seizures
- ☐ Feeding difficulty
- ☐ Birth asphyxia
- ☐ Congenital anomaly specify (_____)
- ☐ Suspected sepsis
- ☐ Jaundice

- ☐ Other: _____

Section F: Outcome

25**.Outcome in NICU**:

- ☐ Survived
- ☐ Died

26**.If Died, Age at Death**: ____ days