The prevalence of neonatal near miss and associated factors in Nepal: a cross-sectional study

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Abstract

Background: Unlike the infant mortality rate, the rate of neonatal mortality has not declined and remains a major health challenge in low- and middle-income countries. There is an urgent need to focus on newborn care, especially during the first 24 hours of birth and the early neonatal period. Determining which factors contribute to neonatal near miss (NNM) can be used to assess health care quality and identify factors capable of correction in the healthcare system to improve neonatal care. Thus, the objective of the current study was to establish the prevalence of NNM and identify its associated factors.

Methods: A hospital-based cross-sectional study was conducted at Koshi Hospital, Nepal. Neonates and their mothers (unspecified maternal age and number of gestational weeks) were enrolled. The key inclusion criterion was the admission of newborn infants to the neonatal intensive care unit at Koshi Hospital. Non-Nepali citizens were excluded. Consecutive sampling was used until the required sample size (i.e., 1,000 newborn infants) was reached. Simple and multiple logistic regression analysis was performed using SPSS® version 24.0.

Results: One thousand respondents were recruited. The prevalence of NNM was 79 per 1,000 live births. Maternal secondary (adjusted odds ratio (AOR]: 0.46, 95% confidence interval (CI]: 0.24–0.88) and tertiary education (AOR: 0.18, 95% CI: 0.05–0.56), multiparity (AOR: 0.52, 95% CI: 0.39–0.86), Caesarean section (AOR: 0.48, 95% CI: 0.19–0.99), and severe maternal morbidity (AOR: 4.51, 95% CI: 2.07–9.84) were significantly associated with NNM.

Conclusions: Parity, severe maternal morbidity, mode of delivery, and maternal education were significantly associated with NNM. Healthcare workers should be aware of the impact of obstetric factors so that earlier interventions, especially the Caesarean section, can be exercised.

Keywords: neonatal near miss, neonatal morbidity, severe maternal morbidity, cross-sectional study, Nepal

Background

The rate of pediatric mortality has long been considered an important indicator of social development, the level of economic prosperity, and healthcare quality. Globally, a 51% decline in neonatal mortality was recorded between 1990 and 2017; however, the decline in neonatal mortality has been slower than that of post-neonatal under-five mortality [1]. At the country level, annual neonatal mortality rates range from 0.9 to 44.2 deaths per 1,000 live births [1]. South Asia had 25 neonatal deaths per 1,000 live births in 2018 [2] and is a hub of the highest number of neonatal deaths along with sub-Saharan Africa [1]; a child born in this region is typically 10 times more likely to die in the first month of life than a child born in a high-income country [2]. The objective of Sustainable Development Goal (SDG) 3 and that of the global Every Newborn Action Plan is to reduce neonatal mortality (i.e., 10 or less per 1,000 live births) by 2030 [3]. The neonatal mortality rate in Nepal was 21 per 1,000 live births in 2016; 57% of the births were institutional deliveries [4]. More than three-quarters (79%) of total neonatal deaths were early neonatal deaths (0-6 days) [4]. There are large variations in neonatal mortality between provinces, i.e. 15 per 1,000 live births in Province 1 and 41 per 1,000 live births in Province 7. The country's flat ecological zones accounted for 60% of neonatal deaths, with 40% of neonatal deaths occurring in hilly and mountainous zones in 2016 [4]. Nepal needs to reduce the rate of neonatal mortality by half in the next 10 years if it is to achieve SDG 3 Goal. Thus, accelerated efforts are needed to address interprovincial disparities with regard to neonatal mortality rates.

Neonatal near miss (NNM) is a novel concept that has recently emerged and is similar to maternal near miss (MNM) concept. It provides vital information required for an evaluation of the quality of care provided in hospital and explores opportunities to improve the performance of healthcare providers [5]. Near-miss events occur three to eight times more often than neonatal deaths [6, 7]. Thus, NNM evaluations can provide abundant evidence of the causal pathways responsible for neonatal deaths [8].

The conceptualization of the term “NNM” in 2009, similar to “MNM,” was proposed by Avenant [9]. That same year, Pileggi *et al.* sought to establish pragmatic NNM criteria using the World Health Organization’s (WHO) Global Survey on Maternal and Perinatal Health (WHOGS) 2005 data [10]. The initial definition of pragmatic markers included very low birth weight (i.e., < 1,500 g), < 30 gestational weeks at birth, or an Appearance, Pulse, Grimace, Activity, and Respiration (Apgar) score of < 7 at five minutes of life in neonates who went on to survive for seven days [10].

Pileggi-Castro *et al.* re-evaluated the NNM definition using WHOGS data and validated their revised definition using the WHO Multi-Country Survey on Maternal and Newborn Health data. According to this definition, NNM refers to “an infant who nearly died but survived a severe complication that occurred during pregnancy, birth, or within seven days of extrauterine life” [11]. The recommended pragmatic marker cut-off criteria were birthweight of < 1,750 g, < 33 gestational weeks, or an Apgar score of < 7 at five minutes of life in newborn infants who go on to survive for seven days. Pileggi-Castro *et al.* [11] also developed management marker criteria that included the use of therapeutic intravenous antibiotics, nasal continuous positive airway pressure, intubation, phototherapy within the first 24 hours, cardiopulmonary resuscitation, vasoactive drugs, anticonvulsants, surfactant administration, blood products, steroids to treat refractory hypoglycemia, and surgery in early neonatal life. In one study, the use of a combination of pragmatic and management markers was demonstrated to be more accurate than the use of either criterion alone in predicting early neonatal mortality [11]. The pragmatic criteria and management markers developed by

Pileggi-Castro *et al.* were shown to have sensitivity and specificity of 93% and 97%, respectively [11].

There is no uniform definition of NNM to this date. Although a vast number of NNM studies are available, health workers in Ghana were unfamiliar with the concept and interpreted NNM on their terms [12]. Systematic reviews on NNM, conducted in 2015 and 2017, recommended that a standard definition for NNM should be developed [13, 14]. A further two studies validated the NNM definitions but did not establish any statistically significant differences between them and the sensitivity and specificity values [15, 16].

Three categories of distinct NNM pragmatic criteria are commonly used in the literature: (1) birthweight of < 1,500 g, < 30 gestational weeks, and an Apgar score of < 7 in the first five minutes of life [6, 10, 17, 18], (2) birth weight of < 1,500 g, < 32 gestational weeks, and an Apgar score of < 7 in the first five minutes of life, [19-21], and (3) birth weight of < 1,750 g, < 33 gestational weeks, and an Apgar score of < 7 in the first five minutes of life [7, 11, 22-25]. Silva *et al.* recommended the addition of mechanical ventilation and congenital malformation to the pragmatic criteria [21].

Literature shows that the management marker criteria are inconsistently applied in most studies [11, 13, 22, 23, 25], and only a few studies have applied management markers that differ to those defined according to the initial NNM concept [6, 26-28]. A 2015 systematic review recommended the addition of antenatal steroids, parenteral nutrition use, congenital malformation (based on the International Statistical Classification of Diseases and Related Health Problems, 10th revision), and admission to the neonatal intensive care unit (NICU) to the management criteria proposed by Pileggi-Castro *et al.* [13]. Researchers in South Asia, in which NNM was assessed, applied pragmatic criteria only [17, 18]. Thus, the current study is the first to use a combination of pragmatic and management criteria in the South Asia region to establish the prevalence of NNM and identify associated factors.

The worldwide prevalence of NNM ranged from 39.2 to 131 per 1,000 live births in 2014 and 2018 [19, 22]. Exceptionally low and high NNM prevalence was recorded in Brazil, i.e., 17 per 1,000 live births in pregnant mothers and 303 per 1,000 live births in type 1 diabetic mothers, respectively [20, 25]. A population-based study conducted in Nepal applied a community-appropriate NMN definition developed by authorities and demonstrated a prevalence of 22 per 1,000 live births [26]. NNM was shown to be caused by birth asphyxia (70%), very low birth weight (17%), neonatal sepsis (10%), and prematurity (3%) [26]. The NNM concept was developed to assess the quality of care provided to pregnant women [29] and their newborn infants, and its application in hospitals was shown to contribute to improvements in obstetric practice and perinatal care [30]. NNM can be utilized as a management tool to assess and identify healthcare limitations, as well as develop public policies with a focus on neonates, considered a particularly vulnerable population group [15]. The NNM definition proposed by Pileggi-Castro *et al.*, which encompasses both pragmatic and management marker criteria, will be used in the current study. In this study, NNM referred to "an infant who nearly died but survived a severe complication that occurred during pregnancy, birth, or within seven days of extrauterine life" [11]. The first week in the life of a newborn infant is critical. The objective of the current study was to identify the prevalence of NNM and its associated factors in Nepal. Shifting the focus towards factors that associate newborns with life-threatening conditions within the first seven days of the crucial period can be information for policymakers for service improvement.

Methods

This cross-sectional study was conducted on 1000 newborn infants, and their mothers admitted to the postnatal ward in Koshi Hospital, Morang, Nepal. It is a referral hospital for Province 1 and offers a NICU service. Koshi Hospital is located in Biratnagar, which is the interim capital city of Province 1 and is the second-most densely populated city after Kathmandu Valley (total population of 1,058,985, with an average of 27,833 annual pregnancies) [31]. The hospital has 35 beds in total in postnatal ward and manages approximately 9,000 annual deliveries. The NICU contains six beds for neonates and admits approximately 45 neonates per month. Only newborn infants from Morang District were enrolled in the current study. Those survived for seven days were included. Consecutive sampling was applied. The sample size was calculated based on the prevalence of NNM using a single proportion formula. With the NNM prevalence of 2.2% [26], the precision of 0.01, and a 20% non-response rate, the calculated sample size was determined to be 1,000 newborn infants.

The research tool comprised of maternal and neonatal medical hospital records. Two research assistants, who were recent nursing undergraduates, collected the data daily. The hospital's medical records on current obstetric history, pregnancy complications, and the data on the newborn infants were reviewed and extracted into a case report form on the day of discharge. Socio-demographic information was obtained from the mothers.

The data were entered and analyzed using IBM SPSS® Statistics 24.0. Frequency and percentages were calculated for the categorical variables; mean, median, standard deviation, and interquartile range were determined for the numerical variables. Simple and multiple logistic regression analyses were used to assess the associated factors. Clinically significant variables in simple logistic regression analysis and those < 0.3 were included in the multiple logistic regression analysis. Adjusted odds ratios (AORs) and corresponding 95% confidence interval (CIs) were calculated.

The outcome variable was the NNM status [11]. The independent variables were ethnicity, religion, wealth index, place of residence, maternal education, paternal education, maternal occupation, paternal occupation, paternal smoking habit, maternal age, age of marriage, duration of the marriage, parity, number of antenatal care visits (ANC), self-reported pre-pregnancy body mass index, maternal haemorrhagic disorders, maternal hypertensive disorders, other maternal systemic disorders, maternal severe management indicators, severe maternal morbidity (SMM) and the sex of the newborn infants.

Results

One thousand newborns and their mothers were recruited for the study between November 2019 and March 2020. There were 18 deaths (12 stillbirths, five intrauterine fetal deaths, and one early neonatal death) during the study period. There were 10 multiple births, and these were treated as a single birth. Of these, four were NNM cases.

The prevalence of NNM was 79 per 1,000 live births in Koshi Hospital (Table 1). Table 1 shows the pragmatic (n = 65) and management markers (n = 44) used to evaluate NNM. The most frequently encountered pragmatic criteria were an Apgar score of < 7 in the first five minutes of life (63%) followed by birth weight of < 1,750 g (31%). All three pragmatic criteria were applicable to only one newborn infant. Of the neonates assessed using pragmatic markers, 35 of the 65 (54%) required NICU admission, and of those evaluated using management markers and admitted to the NICU, 24 of the 44 (68%) fulfilled at least one of the pragmatic marker criteria.

Table 1 Description of pragmatic and management criteria of neonatal near miss cases in Koshi Hospital

Newborn near miss characteristics	n	(%)
Pragmatic criteria		
APGAR Score* < 7 in 5 minutes	41	(63.1)
Birth weight < 1750 g	20	(30.7)
Gestation age < 33 weeks	11	(16.9)
Any pragmatic marker of severity	65	(100.0)
Management criteria		
Use of therapeutic antibiotics	25	(92.6)
Nasal continuous positive airway pressure	19	(70.3)
Cardiopulmonary resuscitation	11	(40.7)
Use of phototherapy in the first 24 hours	6	(22.2)
Any intubation (anytime within the first week)	3	(11.1)
Use of anticonvulsants	2	(7.4)
Use of steroids to treat refractory hypoglycemia	1	(3.7)
Surfactant administration	0	(0)
Use of a vasoactive drug	0	(0)
Use of any blood products	0	(0)
Any surgery	0	(0)
Any management based marker of severity	27	(100.0)
Overall criteria	79	(7.9)

*APGAR Score: Appearance, Pulse, Grimace, Activity, and Respiration

Of the 44 newborns referred for NICU admission, 17 were self-referred to private hospitals; therefore, only 27 were included in Table 1. The majority of the newborn infants in NICU were treated with therapeutic antibiotics (93%) and nasal continuous positive airway pressure (70%).

The socio-demographic, maternal characteristics and characteristics of the newborn infants (with and without NNM) are depicted in Table 2. The proportion of adolescent mothers (< 19 years) with and without NNM was 22% and 10%, respectively.

Table 2 Distribution of socio-demographic and maternal characteristics of participants based on neonatal near miss status

Variables	Neonatal Near Miss (n=79)				non-Neonatal Near Miss (n=921)			
	Mean	SD	n	(%)	Mean	SD	n	(%)
Socio-demographic								
Mother's age (year)[a]	21	(20, 24)			22	(20, 25)		
Age of marriage (year)	18.91	2.43			19.27	2.59		
Duration of marriage (year)[a]	2	(1, 4)			2	(1, 6)		
Ethnicity								
Muslim			16	(20.3)			86	(9.3)
Terai/Madhesi			28	(35.4)			381	(41.4)
Dalits			16	(20.3)			163	(17.7)
Janajati			15	(19.0)			200	(21.7)
Brahmin/Chettri/Newar			4	(5.1)			91	(9.9)
Place of residence								
Urban municipality			48	(60.8)			596	(64.7)
Rural municipality			31	(39.2)			325	(35.3)
Wealth quintile								
Lowest			7	(8.9)			46	(5.0)
Second			14	(17.7)			82	(8.9)
Middle			25	(31.6)			337	(36.6)
Fourth			20	(25.3)			237	(25.7)
Higher			13	(16.5)			219	(23.8)
Mother's education								
None			15	(19.0)			106	(11.5)
Primary			21	(26.6)			187	(20.3)
Secondary			39	(49.4)			494	(53.6)
Tertiary			4	(5.1)			134	(14.5)
Father's education								
None			14	(17.7)			103	(11.2)
Primary			19	(24.1)			133	(14.4)
Secondary			38	(48.1)			512	(55.6)
Tertiary			8	(10.1)			173	(18.8)
Mother's occupation								
Housewife			75	(94.9)			866	(94.0)
Others			4	(5.1)			55	(6.0)
Father's occupation								
Unskilled manual			53	(67.1)			528	(57.3)
Sales and services			18	(22.8)			276	(30.0)
Others			8	(10.1)			117	(12.7)
Father's smoking status								
Yes			16	(20.5)			238	(25.8)
No			63	(79.7)			683	(74.2)
Sex of newborn								
Girl			37	(46.8)			459	(49.8)
Boy			42	(53.2)			462	(53.2)
Maternal								

Variables	Neonatal Near Miss (n=79)				non-Neonatal Near Miss (n=921)			
	Mean	SD	n	(%)	Mean	SD	n	(%)
Parity								
Nulliparous			51	(64.6)			484	(52.6)
Multiparous			28	(35.4)			437	(47.4)
Mode of delivery								
Vaginal			72	(91.1)			762	(82.7)
Caesarean section			7	(8.9)			159	(17.3)
Pre-pregnancy BMI[b]								
Normal			59	(74.7)			690	(74.9)
Underweight			15	(19.0)			160	(17.4)
Overweight and obese			5	(6.3)			71	(7.7)
Number of ANC[c]								
4 visits			35	(44.3)			465	(50.5)
≤3 visits			35	(44.3)			338	(36.7)
≥5 visits			9	(11.4)			118	(12.8)
SMM								
Present			10	(12.7)			35	(3.8)
Absent			69	(87.3)			886	(96.2)
Maternal haemorrhagic disorders								
Present			2	(2.5)			16	(1.7)
Absent			77	(97.5)			905	(98.3)
Maternal hypertensive disorders								
Present			6	(7.6)			12	(1.3)
Absent			73	(92.4)			909	(98.7)
Maternal severe management indicators								
Present			2	(2.5)			16	(1.7)
Absent			77	(97.5)			905	(98.3)

Note: BMI =body mass index, ANC = antenatal care, SMM = severe maternal morbidity
[a] Expressed as median (interquartile range). Skewed to the right

The factors associated with NNM (i.e., 20 independent variables) were evaluated using simple logistic regression analysis (Table 3).

Table 3 Associated factors for neonatal near miss using simple logistic regression analysis

Variables	Crude OR[a]	(95% CI[b])	Wald stat[c] (df)	P value
Mother's age	0.93	(0.87, 0.99)	4.23 (1)	0.040
Age of marriage	0.94	(0.86, 1.04)	1.42 (1)	0.232
Duration of marriage	0.95	(0.89, 1.02)	1.75 (1)	0.186
Ethnicity				
Muslim	1			
Terai/Madhesi	0.23	(0.07, 0.73)	6.21	0.013
Dalits	0.39	(0.20, 0.76)	7.67	0.006
Janajati	0.52	(0.25, 1.10)	2.86	0.091
Brahmin/Chettri/Newar	0.40	(0.19, 0.85)	5.66	0.017
Place of residence				
Urban municipality	1			
Rural municipality	0.84	(0.52, 1.35)	0.49 (1)	0.482
Wealth quintile				
Highest	1			
Fourth	1.42	(0.69, 2.92)	0.91 (1)	0.340
Middle	1.25	(0.62, 2.49)	0.40 (1)	0.527
Second	2.87	(1.29, 6.38)	6.76 (1)	0.009
Lowest	2.56	(0.97, 6.79)	3.61 (1)	0.058
Mother's education				
None	1			
Primary	0.79	(0.39, 1.60)	0.41 (1)	0.520
Secondary	0.56	(0.29, 1.05)	3.28 (1)	0.070
Tertiary	0.21	(0.07, 0.65)	7.26 (1)	0.007
Father's education				
None	1			
Primary	0.89	(0.50, 2.19)	0.02 (1)	0.895
Secondary	0.54	(0.28, 1.04)	3.34 (1)	0.067
Tertiary	0.34	(0.14, 0.84)	5.48 (1)	0.019
Mother's occupation				
Housewife	1			
Others	0.84	(0.29, 2.38)	0.11 (1)	0.743
Father's occupation				
Unskilled manual	1			
Sales and services	0.65	(0.37, 1.13)	2.32 (1)	0.127
Others	0.68	(0.31, 1.47)	0.95 (1)	0.328
Father's smoking status				
No	1			
Yes	0.73	(0.41, 1.28)	1.19 (1)	0.275
Sex of newborn				
Boy	1			
Girl	0.89	(0.56, 1.40)	0.26 (1)	0.609
Mode of delivery				
Vaginal	1			
Caesarean section	0.47	(0.21, 1.03)	3.55 (1)	0.060

Pre-pregnancy BMI				
Normal	1			
Underweight	1.09	(0.60, 1.98)	0.09 (1)	0.761
Overweight	0.82	(0.32, 2.12)	0.16 (1)	0.687
Parity				
Nulliparous	1			
Multiparous	0.61	(0.38, 0.98)	4.14	0.042
Number of ANC				
4	1			
≤3	1.37	(0.84, 2.24)	1.63 (1)	0.201
≥5	1.01	(0.47, 2.12)	0.00 (1)	0.973
SMM				
Absent	1			
Present	3.67	(1.74, 7.72)	11.72 (1)	0.001
Maternal haemorrhagic disorders				
Absent	1			
Present	1.47	(0.33, 6.51)	0.26 (1)	0.612
Maternal hypertensive disorders				
Absent	1			
Present	6.23	(2.27, 17.07)	12.63 (1)	0.000
Maternal severe management indicators				
Absent	1			
Present	1.47	(0.33, 6.51)	0.26 (1)	0.612

Note: BMI =body mass index, ANC = antenatal care, SMM = severe maternal morbidity
[a] Crude odds ratio
[b] Confidence interval
[c] Wald statistics
[d] Degree of freedom

Among 20 independent variables, 14 variables, i.e., ethnicity, wealth quintile, maternal education, paternal education, paternal occupation, paternal smoking habit, maternal age, age of marriage, duration of the marriage, parity, mode of delivery, number of ANC visits, maternal hypertensive disorders, and severe maternal morbidity were identified as associated variables using simple logistic regression analysis with $P < 0.3$. Thus, they were included in multiple logistic regression analysis.

In the multiple logistic regression analysis, mothers' education, parity, mode of delivery, and severe maternal morbidity were found to be significantly associated with NNM. Mothers with secondary (AOR: 0.46, 95% CI: 0.24–0.88) and tertiary education (AOR: 0.18, 95% CI: 0.05–0.56) were at lower odds of experiencing NNM than those with no education.

Multiparous mothers (AOR: 0.52. 95% CI: 0.39–0.86) were less likely to encounter NNM than nulliparous mothers. It was less probable that newborn infants born to mothers who gave birth via Caesarean section would be NNM cases (AOR: 0.48, 95% CI: 0.19–0.99) compared to neonates born to mothers via normal delivery. Similarly, mothers with severe maternal morbidity were at higher odds of giving birth to an infant who would become an NNM case (AOR: 4.5, 95% CI: 2.07–9.84) than those without it (Table 4).

Table 4 Associated factors for neonatal near miss using multiple logistic regression analysis

Variables	Adj *OR*[a]	(95 % *CI*[b])	Wald stat [c] (df)[d]	*P* value
Education of women				
None	1			
Primary	0.66	(0.32, 1.37)	1.22 (1)	0.268
Secondary	0.46	(0.24, 0.88)	5.40 (1)	0.020
Tertiary	0.18	(0.05, 0.56)	8.72 (1)	0.003
Parity				
Nulliparous	1			
Multiparous	0.52	(0.39, 0.86)	6.53 (1)	0.011
Mode of delivery				
Vaginal	1			
Caesarean section	0.48	(0.19, 0.99)	3.89 (1)	0.048
SMM status				
Absent	1			
Present	4.52	(2.07, 9.84))	14.43 (1)	<0.001

Note: SMM = severe maternal morbidity
[a] Adjusted odds ratio
[b] Confidence interval
[c] Wald statistics
[d] Degree of freedom
Note. No significant interaction; no multicollinearity problem; model assumptions met; no influential outliers)

Discussion

The prevalence of NNM was determined to be 79 per 1,000 live births in Koshi Hospital, Nepal, using a combination of pragmatic and management criteria in the current study. Factors significantly associated with NNM were maternal secondary and tertiary education, multiparity, severe maternal morbidity, and Caesarean section. Secondary and tertiary education, multiparity, and Caesarean section were demonstrated to be protective against and lowered the risk of NNM.

The consensus is lacking regarding a standardized period in which NNM is said to occur across countries, which makes it difficult to compare NNM between studies. Some studies have used a near-miss period of 0–6 days [7, 10, 11, 24, 32], while others have utilized 0–27 days [14, 17, 18, 20, 22, 30]. Kale *et al.* recommend extending extrauterine life from seven to 28 days to increase the sensitivity of the definition of near miss by extending the survival period and a decrease in sensitivity when it was applied from 0–364 days [16]. In the current study, a period of seven days was used because three-quarters of neonatal deaths occur within the first week of life, with one quarter taking place in the first 24 hours [33]. Besides, the chance of information bias increases if NNM information is obtained from parents in the community.

The prevalence of NNM in the current study was compared with that reported in other studies that used a definition proposed by Pileggi-Castro *et al.* [11]. It was demonstrated in previous studies that applied the same definition that the prevalence of NNM ranged from 45.1 per 1,000 live births [7] to 72.5 per 1,000 live births [11]. A community study in Nepal defined NNM using an adaptation that was based on the community based integrated management of neonatal and childhood illness criteria and reported NNM prevalence of 22 per 1,000 live births. In another study in Nepal, 37 health workers trained to identify NNM reported 28 such cases in nine months [27]. The NNM definition used in these studies was adapted for suitability at the community level. However, the prevalence of NNM in the current hospital-based study was higher, which could be owing to differences in the definition of NNM and related criteria, as well as the study settings.

Using pragmatic criteria [10], the prevalence of NNM was reported to be 87.6 per 1,000 live births in India in two studies [17, 18], which is higher than the 65 per 1,000 live births in the present study. A possible explanation for the difference in findings is that a survival period of 28 days was used in India study; hence, the sensitivity increased owing to the more extended period applied.

Multiparity was protective against NNM in the current study, which is contrary to the findings of prior studies [23, 34]. The findings of a few studies were in agreement with those of the present study [20, 22]; however, one showed a non-significant association [18]. Both nulliparous and grand-multiparous mothers are at high risk of complications during delivery [35, 36], and this places neonates at risk of adverse outcomes [32, 37, 38]. Nulliparity in older mothers (i.e., $\geq$ 35 years) was found to be a risk factor for adverse perinatal outcomes [39, 40], and a higher likelihood of neonates admitted to NICU born among advanced aged nulliparous women [40-42]. However, in the current study, the proportion of women with more than four children and aged $\geq$ 35 years was small, and this prevented the ability to draw further conclusions.

Two literature reviews suggest that a significant proportion of nulliparous mothers are in their teens, are at increased risk of hypertension, and lack experience in childbirth [43, 44]. This elucidates the likelihood of NNM affecting nulliparous women [32, 38]. Prior studies have shown that first-born infants are at higher risk of neonatal mortality than the second- or third-born infants [43, 45]. However, in some studies, parity was not shown to have an association with neonatal mortality [46].

Elsewhere, a high chance of NNM affecting women undergoing Caesarean section has been demonstrated [20, 21, 23, 47, 48]. In recent studies in India and Ethiopia, although NNM cases were higher in women who underwent Caesarean delivery, a direct association could not be established [7, 18]. Contrary to the findings in the literature, the present study showed that Caesarean delivery was protective against NNM. In support of this, in the United States, the Caesarean section was observed to reduce neonatal mortality in preterm births [49].

The WHO has recommended that Caesarean sections should only be conducted when medically necessary and recommends an upper limit of 15% concerning the percentage of deliveries that should be conducted using this method [50]. In the current study, the overall percentage of births performed using Caesarean delivery was 17%, which is in contrast to that in public hospitals in Nepal (i.e., 12%) [4]. Elective Caesarean sections are not performed at Koshi Hospital. The proportion of Caesarean sections performed in mothers with SMM was two times higher than that performed in mothers without SMM (31% versus 16%) in this study. Previous works of literature show, SMM to be significantly associated with higher rates of current Caesarean section [51-55] and preterm births born to SMM mothers are higher than among mothers without SMM [51, 52]. Timely emergency Caesarean sections performed to manage conditions associated with SMM can prevent an adverse impact on neonatal health [46].

Measures to mitigate medical oversights are in place to manage high-risk pregnancies effectively [56]. Studies in the literature suggest that very low-birth weight newborns delivered by Caesarean section have lower neonatal mortality and low five-minute Apgar scores, which indicates the protective role of Caesarean section [46]. However, overall, there is a lack of consensus in the literature over a popular opinion that neonatal mortality and morbidity is higher in infants who are delivered by Caesarean section [55, 57-59].

In the current study, maternal secondary and tertiary education decreased the likelihood of NNM comparative to a lack of maternal education. Prior studies that assessed socio-demographic factors for NNM have not established a significant association between NNM and maternal education [7, 18, 21-23, 28]. However, a universal association between maternal education and neonatal mortality, especially in developing countries, has been demonstrated [45, 56, 58, 60-63] and supports the current study's findings. Educated mothers have a better knowledge of healthy behaviours, have a more informed approach to self-care, make better health-related choices, and utilize the healthcare system appropriately [37, 64]. An educated mother is also more likely to have a higher socioeconomic status [58].

The current study found an association between severe maternal morbidity and NNM, consistent with the finding of a study carried out in Ethiopia [7] but contradictory to the finding of a study performed in Brazil [25]; therefore, more studies are warranted in this regard to obtain more conclusive findings. Very few studies have explored the relationship between MNM and NNM. One study showed a solid association (OR: 17.15, 95% CI: 1.85–159.12) [25], whereas others have not demonstrated a significant association between MNM and NNM [22, 48]. In support of the current study, there is an association between MNM and higher rates of adverse perinatal outcome born to these mothers [65, 66].

Specific severe maternal morbidity condition (i.e., severe hypertension and pre-eclampsia) is associated with adverse neonatal outcomes [32, 67, 68]. A considerable number of newborn infants with severe hypoxia and neonatal asphyxia have been born to women with MNM [67]. Similarly, maternal obstetric complications have been shown to play a role in the underlying causes of neonatal deaths [45, 69]. Therefore, early screening for poor obstetric conditions during the antenatal period and the appropriate management of intrapartum complications is crucial to ensure a reduction in the number of NNM cases.

The WHO guidelines, which are followed in Nepal as part of the national protocol, recommend a minimum of four antenatal visits for uncomplicated pregnancies. The current finding did not establish any association between ANC and NNM. However, in other research, ANC was associated with neonatal mortality in Nepal [62]. Mixed [20, 22] and converse [7] findings were found. Attending four or more ANC sessions was protective [36, 70], whereas an inadequate number of antenatal visits was associated with neonatal mortality [69, 71].

There are a few possible explanations for this. Firstly, a quarter (24%) of women in Nepal typically receive all seven components of ANC [72]. The majority of Nepal public institutions lack basic ultrasonography and laboratory facilities (i.e., blood and urine testing), which means that a reduced percentage of women undergo blood and urine examinations [72-74], and most pregnant women only receive health education, iron supplementation, blood pressure measurements, and tetanus toxoid [72]. Secondly, there is poor compliance by pregnant mothers with ANC advice [75]. In a qualitative study, it was reported that, in general, pregnant women do not attend ANC follow-up visits as they hope to avoid healthcare workers asking for blood and urine samples. They also do not comply with adequate calcium intake due to poverty. It has been established that women in the wealthiest quintile [73, 76] who reside in urban areas [73, 76] are highly educated [72, 73, 76], nulliparous [76], and aged 30–39 years [72], are more likely to utilize adequate ANC [77]. Hence, even mothers who attended less than the recommended four ANC sessions owing to poor compliance did not show a significant association with NNM in the current study.

Maternal age was significantly associated with NNM when simple logistic regression analysis was applied, but this was not supported using multiple logistic regression analysis. Elsewhere, it has been reported that advanced maternal age (> 35 years) was significantly associated with NNM [22]. Globally, advanced maternal age may increase in pregnancy and obstetric complications; thus, early intervention is recommended to try to prevent adverse outcomes [22]. A significant association has been reported between advanced maternal age [44, 45, 78-82] or younger age (< 20 years) and adverse neonatal outcomes [57, 58, 63, 83, 84]. However, this association was not found in one study [46].

The results of the current study are generalizable to births in government institutions in Nepal. To the best of our knowledge, this is the only study to have explored factors that impact NNM in South Asia using both pragmatic and management criteria.

The study had several limitations. The cross-sectional nature of the research meant that casual association could not be proved. Seventeen of the 44 neonates with conditions requiring admission to the NICU were self-referred to private hospitals; therefore, these data were unavailable. The date of the last menstrual period was used to calculate gestational age; thus, incorrect estimations may have been introduced due to recall bias.

Recommendations

Nulliparity and severe maternal morbidity should be considered high-risk obstetric conditions. Therefore, screening should be performed during the antenatal period, and, if indicated, referral should be made to a tertiary hospital with adequate facilities. Future studies should explore contributory factors to NNM in illiterate women and those with communication barriers, as well as the impact of content and quality of ANC. An evaluation is recommended of the risk of NNM in specific maternal populations, such as older women and those with multiple pregnancies.

Conclusion

Maternal determinants and socioeconomic factors could result in a NNM. The neonates of mothers with severe maternal morbidity are at increased risk of NNM; conversely, Caesarean section, multiparity, and secondary and tertiary education were shown to be protective against NNM in the current study. Caesarean section is encouraged to be exercised as an earlier intervention, especially among women of high-risk obstetric factors.

Abbreviations

SDG: Sustainable Development Goal; NNM: neonatal near miss; WHO: World Health Organization, WHOGS: WHO Global Survey on Maternal and Perinatal Health; NICU: neonatal intensive care unit; MNM: maternal near miss; AOR: adjusted odds ratio; CI: confidence interval; BMI: body mass index; APGAR: Appearance, Pulse, Grimace, Activity, and Respiration; ANC: antenatal care; SMM: severe maternal morbidity

Declarations

Ethics approval and consent to participate

The ethical approval was obtained from the Human Research Ethics Committee Universiti Sains Malaysia (USM/JEPeM/19060356) and Nepal Health Research Council (Reg. no. 336/2019). Written consent of the participants was taken before the interview. Parental consent was taken for women less than 18 years of age.

Consent for publication

Not applicable.

Availability of data and materials

The authors are happy to share anonymized data related to this paper upon receiving a specific request, along with the purpose of that request. Interested parties may contact hayatikk@usm.my

Competing interest

The authors declare that they have no competing interests.

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Authors' contributions

SR designed the study, involved in data collection, analyze data and prepared the manuscript. NMN and NHNH designed the study, involved in data analysis and critically revised subsequent drafts of the manuscript for valuable intellectual content. All authors read and approved the final manuscript.

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