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 the low- and middle-income countries. There is an urgent need to focus on newborn care, especially during the first 24 hours after birth and the early neonatal period. Neonatal near miss (NNM) is an emerging concept similar to that of maternal near miss. NNM events occur three to eight times more often than the neonatal deaths. The objective of this 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, Morang district, Nepal. Neonates and their mothers of unspecified maternal age and number of gestational weeks were enrolled. The key inclusion criterion was the pragmatic and management markers of NNM, and admission of newborn infants to the neonatal intensive care unit (NICU) in Koshi Hospital. Non-Nepali citizens were excluded. Consecutive sampling was used until the required sample size of 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. Severe maternal morbidity (adjusted odds ratio (AOR): 4.51, 95% confidence interval (CI): 2.07–9.84), maternal secondary (AOR: 0.46, 95% 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), and caesarean section (AOR: 0.48, 95% CI: 0.19–0.99) were associated with NNM.

Conclusions: The prevalence of NNM in Nepal was 7.9%. Mothers' obstetric factors, maternal complications and education were associated with NNM. Referral hospitals should have safer access to caesarean section and be prepared to offer NICU intervention to save mothers and their newborns.

Background

The rate of paediatric 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 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 to 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; of the total neonatal deaths, about four-fifths (79%) were early neonatal deaths; and 57% of all births were institutional births [4]. There are large variations in neonatal mortality within provinces, i.e. 15 vs. 71 per 1,000 live births. Nepal needs to reduce the rate of neonatal mortality by half in the next 10 years if it is to achieve SDG target 3.2. 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 the revised definition using the WHO Multi-Country Survey on Maternal and Newborn Health data. The 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 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. Whereas for diagnostic accuracy, the management markers from this definition 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 [11]. The pragmatic criteria and management markers developed by Pileggi-Castro *et al.* were shown to have a sensitivity of 93% and specificity of 97% [11].

There is no uniform definition of NNM to this date although a vast number of NNM studies are available. Systematic reviews on NNM, conducted in 2015 and 2017, had recommended to develop a standard definition for NNM [12, 13]. The worldwide prevalence of NNM ranged from 39.2 to 131 per 1,000 live births in 2014 and 2018 [14, 15]. A population-based study conducted in Nepal applied a community-appropriate NNM criteria adapted from *Pileggi et al.*[10], and adjusted to the local context, demonstrated a prevalence of 22 per 1,000 live births [16]. NNM was shown to be caused by birth asphyxia (70%), very low birth weight (17%), neonatal sepsis (10%), and prematurity (3%) [16].

The NNM definition proposed by Pileggi-Castro *et al.*, which encompasses both pragmatic and management criteria, will be used in this study. Researchers in South Asia, in which NNM was assessed, have 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. 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 objective of the current study was to identify the prevalence of NNM and its associated factors in Nepal.

Shifting the focus from neonatal mortality towards near miss neonates, and its associated factors can be useful 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 district, Nepal. Morang district was chosen based on its high population density and various ethnic groups that represent the community in Nepal. It is a referral hospital for the eastern part of Nepal and offers a neonatal intensive care unit (NICU) service. Koshi Hospital is located in Biratnagar city of Morang district, and is the second-most densely populated city in Nepal (total population of 1,058,985, with an average of 27,833 annual pregnancies) [19]. The hospital has 35 beds in total in postnatal ward and manages approximately 9,000 annual births. The NICU contains six beds for neonates and admits approximately 45 neonates per month.

Mothers of any age and gestational weeks and their newborn those survived for seven days were included in this study. Non-Nepali citizens and non-Morang residents were excluded. 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% [16], 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 and socio-demographic information. 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 of the mother. Newborns in NICU were followed up daily and their information updated after discharge. Socio-demographic information was obtained from the mothers using face-to-face interview.

The data were entered and analysed 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 p-value < 0.3 were included in the multiple logistic regression analysis. Adjusted odds ratio (AOR), corresponding 95% confidence interval (CI), and p-value <0.05 were calculated, and was considered statistically significant.

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, mode of birth, 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.

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). Hospital administration written approval was taken for data collection. The written consent of the participants was taken before the interview. Parental or guardian consent was taken for participants of 18 years and below.

Results

One thousand newborns and their mothers were recruited for the study between November 2019 and March 2020. There were 18 deaths (17 stillbirths 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 pragmatic (*n* = 65) and management markers (*n* = 27) used to evaluate NNM. The most frequently encountered pragmatic criteria was 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 who were admitted to the NICU, 24 of the 44 (54%) fulfilled at least one of the pragmatic marker criteria.

Of the 44 newborns infants born with NNM criteria, 17 were taken to private hospitals; therefore, only 27 newborns medical data could be accessed from the Koshi hospital as shown in Table 1. The majority of the newborn infants in NICU were treated with therapeutic antibiotics characteristics (93%) and nasal continuous positive airway pressure (70%).

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

The socio-demographic, maternal and newborn characteristics with and without NNM are depicted in Table 2. The proportion of adolescent mothers (< 20 years) with and without NNM was 22% and 10%.

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

riables	Neonatal (n=79)		Near	Miss	non-Neonatal (n=921)		Near	Miss
	Mean	SD	n	(%)	Mean	SD	n	(%)
cio-demographic								
ther's age (year)[a]	21	(20, 24)			22	(20, 25)		
e of marriage (year)	18.91	2.43			19.27	2.59		
ration of marriage (year)[a]	2	(1, 4)			2	(1, 6)		
nicity								
uslim			16	(20.3)			86	(9.3)
erai/Madhesi			28	(35.4)			381	(41.4)
alits			16	(20.3)			163	(17.7)
najati			15	(19.0)			200	(21.7)
rahmin/Chettri/Newar			4	(5.1)			91	(9.9)
ce of residence								
rban municipality			48	(60.8)			596	(64.7)
ural municipality			31	(39.2)			325	(35.3)
alth quintile								
owest			7	(8.9)			46	(5.0)
econd			14	(17.7)			82	(8.9)
iddle			25	(31.6)			337	(36.6)
ourth			20	(25.3)			237	(25.7)
igher			13	(16.5)			219	(23.8)
ther's education								
one			15	(19.0)			106	(11.5)
rimary			21	(26.6)			187	(20.3)
econdary			39	(49.4)			494	(53.6)
ertiary			4	(5.1)			134	(14.5)
ther's education								
one			14	(17.7)			103	(11.2)
rimary			19	(24.1)			133	(14.4)
econdary			38	(48.1)			512	(55.6)
ertiary			8	(10.1)			173	(18.8)
ther's occupation								
ousewife			75	(94.9)			866	(94.0)
thers			4	(5.1)			55	(6.0)
ther's occupation								
nskilled manual			53	(67.1)			528	(57.3)
ales and services			18	(22.8)			276	(30.0)
thers			8	(10.1)			117	(12.7)
ther's smoking status								
es			16	(20.5)			238	(25.8)
o			63	(79.7)			683	(74.2)
x of newborn								
irl			37	(46.8)			459	(49.8)
oy			42	(53.2)			462	(50.2)
aternal								
rity								
ulliparous			51	(64.6)			484	(52.6)

ultiparous	28	(35.4)	437	(47.4)
ode of birth				
ormal birth	72	(91.1)	762	(82.7)
aesarean section	7	(8.9)	159	(17.3)
e-pregnancy BMI[b]				
ormal	59	(74.7)	690	(74.9)
nderweight	15	(19.0)	160	(17.4)
verweight and obese	5	(6.3)	71	(7.7)
mber of ANC[c]				
visits	35	(44.3)	465	(50.5)
3 visits	35	(44.3)	338	(36.7)
5 visits	9	(11.4)	118	(12.8)
IM				
resent	10	(12.7)	35	(3.8)
osent	69	(87.3)	886	(96.2)
aternal haemorrhagic orders				
resent	2	(2.5)	16	(1.7)
osent	77	(97.5)	905	(98.3)
aternal hypertensive disorders				
resent	6	(7.6)	12	(1.3)
osent	73	(92.4)	909	(98.7)
aternal severe management licators				
resent	2	(2.5)	16	(1.7)
osent	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 birth				
Normal birth	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	1			
Absent	1.47	(0.33, 6.51)	0.26 (1)	0.612
Present				
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 i.e., ethnicity, wealth quintile, mother's education, father's education, father's occupation, father's smoking habit, mother's age, age of marriage, duration of the marriage, parity, mode of birth, 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, mother's education, parity, mode of birth, 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. Newborns born to mothers who gave birth via caesarean section were less probable to be NNM cases (AOR: 0.48, 95% CI: 0.19–0.99) compared to neonates born to mothers via normal birth. 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]
Education of women			
None	1		
Primary	0.66	(0.32, 1.37)	1.22 (1)
Secondary	0.46	(0.24, 0.88)	5.40 (1)
Tertiary	0.18	(0.05, 0.56)	8.72 (1)
Parity			
Nulliparous	1		
Multiparous	0.52	(0.39, 0.86)	6.53 (1)
Mode of birth			
Normal birth	1		
Caesarean section	0.48	(0.19, 0.99)	3.89 (1)
SMM status			
Absent	1		
Present	4.52	(2.07, 9.84))	14.43 (1)

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. 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 decreased the likelihood of NNM. SMM was found to increase the risk of NNM.

Consensus is lacking regarding a standardized period in which NNM is agreed 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, 20, 21], while others have utilized 0–27 days [13, 15, 17, 18, 22, 23]. Kale *et al.* recommend extending extrauterine life from seven to 28 days to increase the sensitivity of near miss criteria. However, a decrease in sensitivity was found when it was applied for 0–364 days [24]. In the current study, a period of seven days was used because four-fifths of neonatal deaths still occur within the first week of life, with one quarter taking place in the first 24 hours [25]. Besides, the chance of information bias increases if NNM information is obtained from parents in the community, after hospital discharge.

The prevalence of NNM in this study, when compared, were within the range of previous studies, that used the same definition proposed by Pileggi-Castro *et al.* [11], i.e., 45.1 per 1,000 live births [7] to 72.5 per 1,000 live births [11]. A population-based study in Nepal reported NNM prevalence of 22 per 1,000 live births, which is lower than the prevalence of NNM in the current hospital-based study. Possible reasons may be due to differences in used NNM definition and criteria, as well as the study settings.

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

Multiparity decreased the likelihood of NNM in the current study, similar to few other studies [15, 23]. Studies from southern and northern Ethiopia reported that multiparity was a risk factor for NNM [26, 27]. A recent prospective cohort study in Ethiopia reported that grand multiparity was a risk factor for perinatal mortality among women with MNM [28].

Both nulliparous and grand-multiparous mothers were at high risk of developing complications during birth [29, 30], which places neonates at risk of adverse outcomes [20, 31, 32]. Nulliparity among advanced aged mothers (≥ 35 years) was a risk factor for adverse perinatal outcomes [33, 34]. Neonates born to advanced aged nulliparous women had a higher likelihood of neonates admitting to NICU [34-36]. However, in this study, the proportion of women with more than four children and aged ≥ 35 years was small, which prevents the ability to draw further conclusions.

Literature reviews suggest that a significant proportion of nulliparous mothers are at increased risk of hypertension and lack experience in childbirth [37, 38]. This elucidates the likelihood of NNM affecting nulliparous women [20, 32]. Prior studies have shown that first-born infants are at higher risk of neonatal mortality than second- or third-born infants [37, 39]. However, in some studies, parity was not shown to be associated with neonatal mortality [40].

Elsewhere, a high chance of NNM affecting women undergoing caesarean section has been demonstrated [23, 26, 41-43]. In recent studies in India and Ethiopia, although NNM cases were higher in women who underwent caesarean birth, a direct association could not be established [7, 18]. Contrary to the findings in the literature, the present study showed that caesarean section was protective against NNM. In support of this finding, in the United States, the caesarean section was observed to reduce neonatal mortality in preterm births [44]. Another study in Gambia*,* found that among women with severe obstetric complications, risk of stillbirth among normal birth increased by four-fold compared to caesarean birth [45].

The WHO recommends caesarean sections only when medically necessary and recommends an upper limit of 15% [46]. In the current study, the overall percentage of births via caesarean birth was 17%, which is higher than 12% reported in public hospitals in Nepal [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 literature works show SMM to be significantly associated with higher current caesarean section [47-51], and higher number of preterm births were born to SMM mothers than mothers without SMM [47, 52]. An increase in fetal mortality and a higher number of babies admitted to NICU for seven days or longer was found together with an increase in the number of caesarean birth [50]. A systematic review and meta-analysis showed that maternal and perinatal outcomes were often linked [53]. Mothers at high risk of maternal complications that gave birth at the second stage via caesarean sections and the babies born to these women have a low Apgar score at 5 min. They were more likely to be admitted to NICU, than the mothers who gave birth at the first stage [53].

Caesarean birth is the urgent action the specialist takes to manage the severity of obstetric and fetal conditions to prevent disease progression [54, 55], but chances of intraoperative complications and haemorrhage following this procedure is high in the low- and middle- income countries [53]. Thus, the timely operational procedure can prevent an adverse impact on neonatal health among SMM mothers [40, 53], or at times exposed mothers to the risk of complications and infections [53, 56]. A caesarean section could be a confounder if an operational procedure is performed only among fetus with a greater likelihood of being born alive [57]. However, overall, there is a lack of consensus in the literature over a popular opinion that neonatal mortality and morbidity are higher in infants delivered by caesarean section [51, 53, 58-60].

In the current study, maternal secondary and tertiary education decreased the likelihood of NNM. Prior studies that assessed socio-demographic factors for NNM, have not established a significant association between NNM and maternal education [7, 15, 18, 26, 41]. However, a universal association between maternal education and neonatal mortality, especially in the low-income countries, has been demonstrated [39, 59, 61, 62], and supports current study's findings. In addition, educated mothers are more likely to come from a higher socioeconomic status [59], 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 [31, 63].

The current study found an association between severe maternal morbidity and NNM, consistent with the finding of a study in Ethiopia [7], but contradictory to a study in Brazil [64]. However, very few studies have explored the relationship between MNM and NNM. One study showed a strong association (OR: 17.15, 95% CI: 1.85–159.12) [64], whereas others have not demonstrated a significant association between MNM and NNM [15, 43]. Mixed association existed between hemorrhage and hypertensive disorder during pregnancy and NNM in southern Ethiopia [26] and Brazil [23]. In support of the current study, there existed an association between MNM and higher rates of adverse perinatal outcome born to these mothers [45, 57, 65, 66]. Tura *et al.* claim that adverse perinatal outcomes among MNM women is self-evident given the fact that MNM are identified using severe clinical criteria along with organ disfunction, which was also supported by their findings [28].

Among women with severe maternal morbidity condition, the odd of giving birth to adverse neonatal outcomes is higher [20, 67-69]. A considerable number of newborn infants with severe hypoxia [67], low birth weight [57], and neonatal asphyxia [57, 67] were born to women with MNM. There was two-fold increase in stillbirth risk among women with more than one complications in Gambia [45]. Similarly, maternal obstetric complications have been shown to play a role in the underlying causes of neonatal deaths [39, 70]. 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 current study finding did not establish any association between ANC and NNM unlike a study in southern Ethiopia, adequate ANC visits was positively associated with NNM [26]. Mixed [15, 23] and converse [7] findings were found. Attending four or more ANC sessions was protective [30, 71], whereas an inadequate number of antenatal visits was associated with risk of neonatal mortality [70, 72], and adverse birth outcome [69].

Exploring possible explanations for non-association in this study were, firstly, only a quarter (24%) of women in Nepal receive all seven components of ANC [73]. The majority of Nepal public institutions lack basic ultrasonography and laboratory facilities (i.e., blood and urine testing) [73-75], and most pregnant women only receive health education, iron supplementation, blood pressure measurements, and anti-tetanus toxoid [73]. Secondly, there is poor compliance by pregnant mothers with ANC advice [76]. Hence, women with or without attending recommended four ANC sessions, owing to poor compliance, did not show a significant association with NNM in the current study.

Globally, advanced maternal age (≥ 35 years) may increase in pregnancy and obstetric complications [15]. With advancing age, the prevalence of pre-existing conditions appear to increase and also the risk of caesarean birth, contributing to the increased risk to the fetus [77]. Advanced maternal age [15] and under age (<18 years)[27] was significantly associated with NNM. Similarly, significant association has been reported between advanced maternal age [38, 39, 69] or younger age (< 20 years) [57, 58, 62], and adverse neonatal outcomes. Secondary analysis of the WHO multi-country survey on maternal and newborn health findings showed that advanced maternal age significantly increased the risk of stillbirths and perinatal mortalities [77]. However, no association was established between maternal age and NNM in this study.

The results of the current study are generalizable to births in the 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 of the risk of NNM is recommended in specific maternal populations, such as advanced aged women, and those with multiple pregnancies. Near misses are lives saved due to timely intervention, so future studies should standardize this definition.

Conclusion

Maternal determinants and sociodemographic factors could result in an NNM. The neonates of mothers with severe maternal morbidity are at increased risk of NNM; conversely, caesarean section, multiparity, and secondary and tertiary education reduced likelihood of NNM. Although the caesarean section was found to reduce odds of NNM, this association requires additional evidence and safer access of caesarean section should be ensured. Referral hospitals should be prepared to offer adequate emergency neonatal care to save nearly missed newborn especially through NICU intervention.

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

All data are available within the manuscript.

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, analyse 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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