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ORIGINAL RESEARCH ARTICLE

Maternal socio-biological and obstetric factors associated with neonatal near miss at a specialised public mother and child hospital in Johannesburg, South Africa: A case control study

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Abstract

The aim of this case-control study was to assess neonatal near miss rate and associated maternal socio-biological and obstetric factors at a specialised mother and child teaching hospital in Johannesburg, South Africa. The study population comprised of 744 mother-infant pairs (372 near misses and 372 control). The neonatal near miss rate was 110 per 1000 deliveries. The mean maternal age and median parity for the study population were 28.07 (±5.97) years and 2(IQR: 1-2) respectively. Advanced maternal age, substance abuse underweight, preterm delivery, pregnancy specific antenatal disorders, delivery by interns and registrar doctors were statistically associated with neonatal near miss (NNM). Attention should be paid to these factors in order to improve neonatal outcomes. *(Afr J Reprod Health 2025; 29 [4]: 49-62).*

Keywords: Neonatal; near-miss; obstetric; maternal; outcomes; factors

Résumé

L'objectif de cette étude cas-témoins était d'évaluer le taux d'accouchements évités de justesse néonatals et les facteurs sociobiologiques et obstétricaux maternels associés dans un hôpital universitaire spécialisé en maternité et pédiatrie de Johannesburg, en Afrique du Sud. La population étudiée comprenait 744 couples mère-enfant (372 accouchements évités de justesse et 372 témoins). Le taux d'accouchements évités de justesse néonatals était de 110 pour 1 000 accouchements. L'âge maternel moyen et la parité médiane de la population étudiée étaient respectivement de 28,07 ans (± 5,97) et 2 ans (IQR : 1-2). L'âge maternel avancé, la toxicomanie, l'insuffisance pondérale, l'accouchement prématuré, les troubles prénatals spécifiques à la grossesse, l'accouchement par des internes et des médecins généralistes étaient statistiquement associés aux accouchements évités de justesse néonatals (APN). Il est important de prêter attention à ces facteurs afin d'améliorer les résultats néonatals. *(Afr J Reprod Health 2025; 29 [4]: 49-62).*

Mots-clés: Néonatal, accouchement évité de justesse, obstétrique, maternel, résultats, facteurs

Introduction

A neonatal near miss (NNM) is defined as a neonate, who, within the first 28 days of life, has significant morbidity and would otherwise have died but survives either due to chance or as a result of medical intervention[1]. The concept of NNM is analogous to that of maternal near miss (MNM) that is used to monitor the quality of maternal health and contemporary maternity practice, however, unlike MNM, NNM is underutilised. Likewise, NNM can be used to assess the quality of prenatal and intrapartum care in neonates with severe morbidity[2]. Previously, much of the research in this area has concentrated on neonatal mortality (NM), which represents is an epidemiological tip of the iceberg of poor neonatal outcomes, as there are significantly more instances of neonatal near misses (NNMs)

compared to neonatal deaths. A study by Surve *et al*, in Mumbai, India, reported that the ratio of NNM to neonatal mortality is approximately 9.4:1[1]. Therefore a more sensitive marker of the quality of perinatal and neonatal care would be the prevalence and pattern of NNM cases at a given health facility. Furthermore, in addition to patients demanding explanations for poor neonatal outcomes, NNMs may result in permanent or chronic debilitating conditions in adulthood. Assessing NNM may yield valuable insights into the quality of perinatal and neonatal care in South Africa, which has experienced a drastic upsurge in litigations related to poor quality of intrapartum and perinatal care[3]. A NNM surveillance system can assists in identifying deficiencies in antenatal and intrapartum care and to improve the quality of maternity and neonatal care, thereby minimising the potential for litigation.

Globally, the rates of NNM rates vary between 21% and 72% due to the differences in the diagnostic criteria that is used in different settings[1]. To standardise the definition, Pileggi Castro *et al*[3] developed a nearly universal NNM criteria after secondary data analysis of two World Health Organization (WHO) databases, the WHO Global Survey on Maternal and Perinatal Health, and WHO Multi-country Survey on Maternal and Newborn Health. They proposed a more comprehensive NNM criteria based on pragmatic and management related factors. The pragmatic criteria include variables such as low APGAR score at 5 minutes of life (<7); low birth weight (<1750 g); and low gestational age (<33 weeks) and the management criteria, use of intravenous antibiotics, nasal continuous positive airway pressure, intubation within the first week of life, administration of phototherapy within the first day of life, need for cardiopulmonary resuscitation, use of vasopressors, anticonvulsants, or steroids for hypoglycaemia, administration of surfactant, transfusion of blood products, and performance of any neonatal surgery[1,3]. All the a factors listed above are associated with a sick neonate and risk of neonatal death.

Various maternal socio-biological and obstetric-related factors have also been associated with NNMs. These factors include, amongst others, extremes of maternal age, infections such as syphilis, severe pre-eclampsia, antepartum haemorrhage (APH), preterm delivery, low birth weight, inadequate intrapartum care, intrapartum birth asphyxia, birth trauma, and caesarean section delivery[4-6]. However, some women have no identifiable obstetric or medical conditions at the time of experiencing a perinatal death or NNM. Local obstetric and neonatal practices, health systems, and environmental factors may also impact on the prevalence of NNM in different settings, leading to regional variations and subnational incidences of the condition[7]. All of the above underscores the importance of investigating the factors that contribute to NNMs in different settings and use the information to inform targeted interventions.

Under apartheid, South Africa, classified as an upper-middle-income country (UMIC), faced significant challenges in maternal and neonatal outcomes as a result of discriminatory policies and practices. Following the democratic transition in 1994, concerted efforts have been implemented to improve access to and the quality of maternal and neonatal healthcare services for historically disadvantaged groups, thereby improving healthcare access for a larger segment of the population. This progress has provided an opportunity to assess the quality of maternal and neonatal healthcare services offered to some of society's most vulnerable groups, specifically neonates, by utilizing a standardized tool such as the NNM.

We therefore conducted a case control study to determine the incidence of NNM and associated maternal socio-biological and obstetric factors at a high-volume, public, specialised mother and child teaching hospital in Johannesburg, South Africa, with the hope of generating evidence to inform clinical practice.

Methods

Study design

This is a case-control study of 744 mother and newborn pairs conducted at a specialised, high volume public mother and child teaching hospital in Johannesburg, South Africa), from 1 January 2016 to 31 December 2016.

Study site

The study site is a high-volume, specialised mother and child hospital located in the Gauteng province.

The study site is one of the teaching hospitals associated with the University of the Witwatersrand. The hospital conducts between 13,000 and 15,000 deliveries per annum and primarily serves previously disadvantaged population groups.

Study sample

A sample size of 744 mother-infant pairs was determined using the ClinCalc.com online sample size calculator, (assuming 80% power, 95% confidence interval and 5% margin of error with a 1:1 sample of cases and control) (https://clincal.com/stats/samplesize.aspx). The prevalence of NNM was taken as 7.25%, as it was reported in the WHO Multicounty Survey on Maternal and Newborn Health (2010-2011)[4]. The neonatal database identified 1517 NNM cases between 1 January to 31 December 2016. In-hospital deliveries were 13151, while babies born before arrival (BBA) were 618, making a total of 13769 deliveries. A random number table was used to select 372 cases from the NNM cases. Similarly, 372 controls were selected from 12252 non-NNM babies during the same period.

Study population , inclusion, exclusion criteria and data collection

There was a total of the 13151 in hospital deliveries and 1517 NNMs during the study period. This study is based on 744 mother-infant pairs (372 NNMs and 372 controls) Maternal sociodemographic and obstetric characteristics of babies diagnosed with NNM based on the hospital's neonatal database and controls were extracted from the database, using a Research Electronic Data Capture (REDCap) online data collection tool. The database stored case information for babies admitted to the neonatal intensive care unit (NICU) and neonatal admission ward. These case files were the pool from which neonatal near miss cases were selected. Babies that had normal outcomes (case controls) were randomly selected from the admissions register of the postnatal ward, as this was the destination for all the babies with a normal outcome, prior to discharge (Fig1). The diagnosis of NNM was made using either pragmatic or management criteria for NNM as used by Santos *et al*[8] (Fig 1). The rationale for using these criteria for the identification of neonatal near miss was because recent studies have shown a growing acceptance of these criteria as the standard for defining NNM. They were originally described by Pileggi-Castro *et al*[3] in their 2013 publication and have subsequently been used in other studies exploring NNM[7-10]. The control group (n=372) comprised of normal babies that were born during the study period. All early neonatal deaths were excluded from the study, because they did not satisfy the definition of a neonatal near miss. Furthermore, all files with missing information were excluded from analysis of the relative missing variables.

Figure 1. Selection matrix and neonatal near miss criteria

Neonatal near miss cases were obtained from the database of babies admitted to either ward paediatric ward or Paediatric Intensive Care Unit (PICU). Normal cases were recruited from the postnatal wards admissions lists. Maternal files for both groups were then retrieved from records department for analysis. Pragmatic and Management inclusion criteria are as listed in the figure.

Statistical analysis

Data was exported from REDCap to Stata® version 17.0 (STATACorp, Texas, U.S.A.) statistical software for analysis. Continuous variables such as maternal age or gestational age at delivery were described using mean (±standard deviation) or median (interquartile range), if not normally distributed. Categorical variables, such as mode of delivery, were described using frequencies and percentages. The overall NNM and perinatal mortality rate (PMR) was calculated by dividing the annual and perinatal mortality by the total deliveries in 2016 and expressed per 1000 births.

Some continuous variables, such as age, were categorized into clinically relevant categories. Age was categorized into teenager (age <20 years), normal age (20-34 years) and advanced maternal age (≥ 35 years). Continuous variables between the cases and controls were compared using Student's t-test or Mann-Whitney U test (if not normally distributed). The association between categorical variables and outcome (near miss vs normal) was assessed using the Pearson's Chi square test (or Fischer's exact test for small numbers).

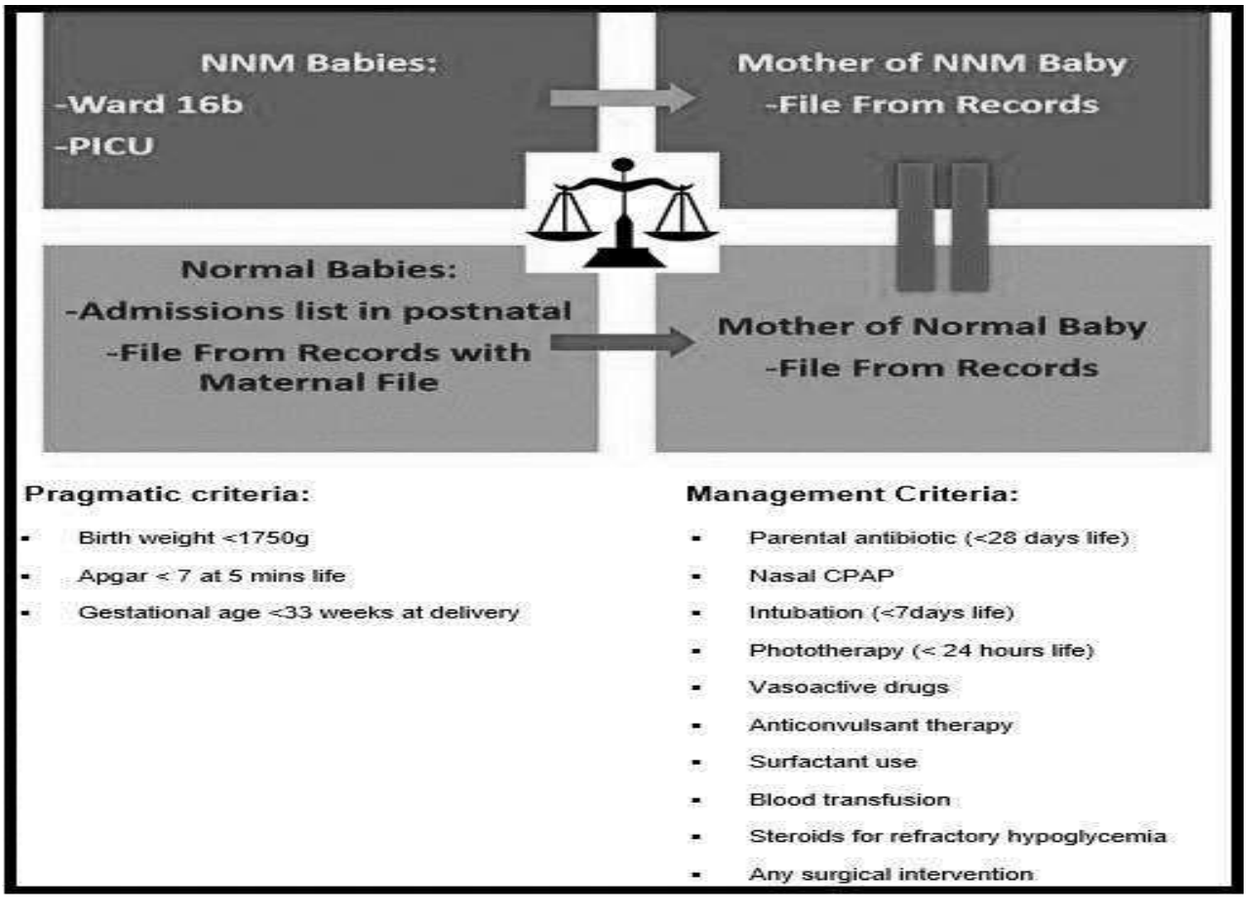

Figure 1: Selection matrix and neonatal near miss criteria

This data was further subjected to univariable logistic regression using NNM as the outcome and maternal factors as explanatory variables.

Subsequently multivariable modelling was conducted using the backward elimination technique and only variables with p-value<0.2 were included in the multivariable model. Additional variables from literature review were included due to their presumed clinical relevance or suggested relevance. Eleven variables were included in the final model: age; race; non-sober social habits such as smoking, alcohol and illicit drug use; parity; body mass index (BMI); Human Immunodeficiency Virus (HIV) status; gestational age at delivery; chronic medical disorder; antenatal pregnancy specific disorder; delivering healthcare worker; and delivery type. Crude and adjusted odds ratios (with 95% confidence interval) were reported. The statistical significance level was set at a confidence interval of 95% (p-value of 0.05). Two-tailed test of significance was assumed. Collinearity of the variables were assessed using Variance Inflation Factor.

Ethics clearance

Ethical clearance was obtained from the Human Ethics Research Committee (Medical) of the University of the Witwatersrand (Clearance certificate no. M180108). The data were anonymised to ensure confidentiality. The Ethics Committee waived the requirement for informed consent from the parents/guardians of the infants, as this study was retrospective in nature.

Results

Of the 13769 births that occurred at the study site, from 1 January to 31 December 2016, the perinatal deaths for 2016 were 400, giving a perinatal mortality rate of 30.4 per 1000 births. Based on the pragmatic and management criteria 1517 NNM cases were identified from the neonatal database.

Therefore, the NNM rate was 110 per 1000 births with an NNM: PMR ratio of 3.6:1.

Sociodemographic Characteristics

The mean maternal age of the study population was 28.1(±5.97) years. About 6.5% (n=48) and 15.19 % (n=113) of the study population were teenagers and women with advanced maternal age respectively. Furthermore, teenage pregnancy and advanced maternal age were more prevalent in the NNM group as compared to the controls (7.5% vs 5.4% and 19.4% vs 11 respectively, p-value=0.002). There was, however, no statistically significant difference between the two groups with respect to the other sociodemographic factors (Table 1).

Antenatal care characteristics

The antenatal profile of the study population is also summarised (Table1). Both NNM and control groups were similar in terms of pregnancy risk factors, rapid plasma regain (RPR), rhesus group (Rh), human immunodeficiency virus (HIV) and HIV treatment. Multiple pregnancies were more frequent in the near miss group when compared to the controls (8.6% vs 5%, p-value<0.001). The median gestational age at delivery was lower among the NNM compared to the controls (36 (31-39) vs 38 (37 – 40), p value<0.001). Early preterm deliveries ($\leq 33^{+6}$ weeks) were five-fold as common among the NNM compared to the controls (41.52% vs 7.71%, p-value<0.001). The following had higher incidence among the NNM compared to the controls: Previous pregnancy termination (TOP (11.83% vs 6.72%, p-value 0.016); unbooked status (6.72% vs 3.49%, p-value=0.046); and less than three antenatal visits (26.77% vs 16.81%, p-value=0.002). Anaemia was more prevalent in the control group (30.91% vs 26.34%, p-value<0.001), however, there was a greater number of individuals with untested haemoglobin levels in the NNM group (11.02% vs 3.49%, p-value<0.001). Frequencies of pre-existing medical disorders were not significantly different across the study groups. Pregnancy specific complications were generally more frequent in the near miss group and 35.02% of the study population were complicated by hypertensive disorders in the index pregnancy. Furthermore, the following complications were more common in the near miss compared to the control group: hypertensive disorders (38.39% vs 24.24%, p-value<0.001), preterm labour (22.75% vs 13.64%, p-value<.001), and antepartum haemorrhage or APH (8.06% vs 4.55%, p-value<0.001). Interestingly, the diagnosis of foetal distress occurred more frequently in the control group (18.18% vs 7.11%, p-value<0.001).

Intrapartum and delivery factors

Intrapartum and delivery factors are also seen in Table 2. There was no statistically significant difference in terms of intrapartum factors such as mode of delivery, induction methods, augmentation of labour, partogram use, electronic foetal monitoring and delivery difficulties, between the two groups. However, emergency caesarean section was performed at a greater frequency in the near miss group compared to controls (77.97% vs 60.19%, p-value<0.001). In contrast, the following were higher in the control compared to the NNM group: elective caesarean section delivery (39.81% vs 22.03%, p-value<0.001) and spontaneous labour (94.98% vs 89.38, p-value=0.024). Electronic foetal monitoring was performed in about four-fifths (81%, n=606) of the study population. There was no statistically significant difference between the two groups, regarding the frequency of performing electronic foetal monitoring. Pathological (18.56% vs 11.76%, p-value=0.026) and suspicious traces (19.93% vs 15.36%, p-value=0.026) were more common among the near miss group compared to the controls. Most of the deliveries were conducted by registrar doctors or midwives (49.06% and 31.32% respectively). NNM was more prevalent in patients that were delivered by registrar doctors (58.06% vs 40.05% control, p-value<0.001).

Regression analyses

Univariable logistic regression analysis (Table 3) showed that; advanced maternal age, social habits, underweight, preterm delivery, previous termination of pregnancy (TOP), unbooked status, untested haemoglobin, chronic medical disorder, antenatal pregnancy complication, induction of labour, pathological trace, delivery by an intern or registrar, multiple pregnancy, two or less antenatal clinic visits, having a high-risk classification and emergency caesarean section delivery, were all significantly associated with an increased prevalence of NNM.

Table 1: Comparison of the sociodemographic and antenatal care characteristics of NNM patients and controls.

	NNM (%)	Controls (%)	Total (%)	p-value
Characteristics				
Age (years) (n=744)				
Mean (±SD)	28.50 (±6.4)	27.66 (±5.8)	28.07 (±5.97)	0.066[a]
≤19	28 (7.53)	20 (5.38)	48 (6.45)	**0.002*[b]**
20-34	272 (73.12)	311 (83.6)	583 (78.36)	
≥35	72 (19.35)	41 (11.02)	113 (15.19)	
Race (n=735)				
Black	317 (86.14)	317 (86.38)	634 (86.26)	0.435[c]
White	9 (2.45)	9 (2.45)	18 (2.45)	
Coloured	36 (9.78)	30 (7.18)	66 (8.98)	
Indian/Asian	6 (1.63)	11 (3.00)	17 (2.32)	
White	317 (86.14)	317 (86.38)	634 (86.26)	
Employment (n=713)				
Employed	112 (31.37)	136 (38.20)	248 (34.78)	0.056 [b]
Unemployed	245 (68.63)	220 (61.80)	465 (65.22)	
Habits (n=744)				
No Habits	333 (89.52)	356 (95.70)	689 (92.61)	**0.031*[c]**
Alcohol use	7 (1.88)	4 (1.08)	11 (1.48)	
Smoking	16 (4.30)	10 (2.69)	26 (3.49)	
Recreational drugs	16 (4.30)	2 (0.54)	18 (2.42)	
Gestation (n=744)				
Singleton	340 (91.4)	367 (98.66)	707 (95.03)	**<0.001***
Multiple	32 (8.60)	5 (1.34)	37 (4.97)	
Gravidity (n=744)				
Median (IQR)	2(1-3)	2(2-3)	2(1-3)	0.8264
Primigravida	101 (27.15)	85 (22.85)	186 (25.00)	0.176
≥2 Pregnancies	271 (72.85)	287 (77.15)	558 (75.00)	
Parity (n=740)				
Median (IQR)	2(1-2)	2(1-2)	2(1-2)	0.4661
Nulliparous	113 (30.38)	102 (27.72)	215 (29.05)	0.649
Multiparous (P1-P4)	256 (68.82)	264 (71.74)	520 (70.27)	
Grand Multiparous (≥5)	3 (0.81)	2 (0.54)	740 (100.00)	
History of TOP (n=744)				
No Previous TOP	328 (88.17)	347 (93.28)	675 (90.73)	**0.016***
Previous TOP	44 (11.83)	25 (6.72)	69 (9.27)	
History of Ectopic (n=744)				
No Previous Ectopic	340 (91.40)	346 (93.01)	686 (92.20)	0.412
Previous Ectopic	32 (8.60)	26 (6.99)	58 (7.80)	
Delivery Gestational Age (n=680)				
Median (IQR)	36 (31-39)	38 (37-40)	38 (35-39)	**<0.001***
$\leq 33^{+6}$	137 (41.52)	27 (7.71)	164 (24.12)	**<0.001***
$34\text{-}37^{+6}$	70 (21.21)	77 (22.00)	147 (21.62)	
$38\text{-}40^{+6}$	115 (34.85)	236 (67.43)	351 (51.62)	
≥41	8 (2.42)	10 (2.86)	18 (2.65)	
Booking Status (n=744)				
Booked	347 (93.28)	359 (96.51)	706 (94.89)	**0.046***
Unbooked	25 (6.72)	13 (3.49)	38 (5.11)	
Time of Booking (n=744)				
Booked $\leq 13^{+6}$/40	34 (9.14)	41 (11.02)	75 (10.08)	0.05
Booked ≥14/40	309 (83.06)	317 (85.22)	626 (84.14)	
Unspecified	29 (7.8)	14 (3.76)	43 (5.73)	
Antenatal Visits (n=676)				

≤2 visits	87 (26.77)	59 (16.81)	146 (21.60)	**0.002***
≥3 visits	238 (73.23)	292 (83.19)	530 (78.40)	
Antenatal Risk Class (n=744)				
Low	179 (57.53)	214 (48.12)	393 (52.82)	0.055
Medium	62 (16.67)	56 (15.05)	118 (15.86)	
High	54 (14.52)	37 (9.95)	91 (12.23)	
Unclassified	77 (20.70)	65 (17.47)	142 (19.05)	
BMI (n=382)				
≤19.8 (underweight)	16 (8.89)	8 (3.96)	24 (6.28)	0.267
19.9-24.9 (normal)	45 (25.00)	62 (30.69)	107 (28.01)	
25-29.9 (overweight)	57 (31.67)	70 (34.65)	127 (33.25)	
30-34.9 (obese class1)	33 (18.33)	35 (17.33)	68 (17.80)	
35-39.9 (obese class2)	17 (9.44)	19 (9.41)	36 (9.42)	
≥40 (obese class3)	12 (6.67)	8 (3.96)	20 (5.24)	
Booking Hb (g/dL) (n=744)				
Mean (±SD)	11.96 (1.91)	11.93 (1.59)	11.95 (1.77)	0.8153[b]
Normal (≥11)	233 (62.63)	244 (65.59)	477 (64.11)	**<0.001***
Anaemic (≤10.9)	98 (26.34)	115 (30.91)	213 (28.63)	
Untested	41 (11.02)	13 (3.49)	54 (7.26)	
RPR test Status (n=744)				
Non-Reactive	339 (91.13)	351 (94.35)	690 (92.74)	0.200
Reactive	5 (1.34)	2 (0.54)	7 (0.94)	
Unknown	28 (7.53)	19 (5.11)	47 (6.32)	
Rh Group Status (n=744)				
Positive	351 (94.35)	357 (95.97)	708 (95.16)	0.559
Negative	10 (2.69)	8 (2.15)	18 (2.42)	
Unknown	11 (2.96)	7 (1.88)	18 (2.42)	
HIV Status (n=744)				
Positive	64 (17.20)	74 (19.89)	138 (18.55)	0.635
Negative	277 (74.46)	269 (72.31)	546 (7.39)	
Unknown	31 (8.33)	29 (7.80)	60 (8.06)	
HIV Treatment (n=138)				
HIV negative	308 (82.80)	298 (80.11)	606 (81.45)	0.728

BMI: Body mass index, Hb: Haemoglobin, IQR: HIV: Human immunodeficiency virus, Inter quartile range, NNM: Neonatal near miss, RPR: Rapid plasma reagin, Rh: Rhesus, SD: Standard deviation, TOP: Termination of pregnancy, *P-value<0.05, [a]Student's t-test, [b]Pearson's chi-square test, [c]Fischer's exact test

Deliveries by a community service doctor and elective caesarean section deliveries were associated with a decrease in NNM (p-value <0.05). Table 3 is a summary of the above. After adjusting for potential confounders, in a multivariable regression model, the study found that patients with advanced maternal age had about 2.7-fold odds of NNM (OR=2.65 95% CI: 1.10-6.41, p=0.029), when compared to women aged 20-34 years. Women who had non-sober social habits were about 4.5-fold more likely to experience NNM, when compared to women with no habits (OR=4.48, 95% CI: 1.54-13.05, P=0.006). Those who were underweight (BMI ≤19.8) were 4-fold more likely to have babies with NNM, when compared to normal weight patients (OR=4.40, 95% CI: 1.2215.80, P=0.023). Gestational age $<33^{+6}$ weeks was associated with a four and half-fold increased odds of NNM, when compared to term babies (OR=4.56, 95% CI: 1.92-10.83, p=0.001). Women whose pregnancies were complicated with an antenatal pregnancy disorder had about 5-fold increased odds of having NNM, when compared to women who had no complication (OR=5.19, 95% CI: 2.61-10.30, P<0.001).

Intern doctor delivery was associated with 44-fold increase in NNM compared to midwife deliveries (OR=44.7, 95% CI: 2.27-880.06, P=0.012), whilst registrar doctor delivery was associated with a near 6-fold increase in NNM (OR=5.91, 95% CI: 1.61-21.74, p=0.008). At multivariable logistical regression level, both elective and emergency caesarean section delivery were found to be protective. Elective CS was associated with a 78% reduction in odds of having a NNM (OR=0.22, 95% CI: 0.050.87, p=0.031).

Table 2: Comparison of intrapartum events between cases and controls.

			Total (%)	[a]p-value
	NNM (%)	**Controls (%)**		
Characteristics				
PPrevious CS (n=167)				
No previous CS	303 (81.45)	274 (73.66)	577 (77.55)	**0.038***
1 Previous CS	49 (71.01)	70 (71.43)	119 (71.26)	
2 Previous CS	17 (24.64)	27 (27.55)	44 (26.35)	
≥3 Previous CS	3 (4.35)	1 (1.02)	4 (2.40)	
Mode of Delivery (n=744)				
Vaginal Delivery	145 (39.98)	156 (41.96)	301 (40.46)	0.565
NVD (in hospital)	129 (34.68)	143 (38.44)	272 (36.56)	
BBA (out of hospital)	13 (3.49)	12 (3.23)	25 (3.36)	
Assisted Vaginal Delivery	3 (0.81)	1 (0.27)	4 (0.58)	
Caesarean Section Delivery	227 (61.02)	216 (58.06)	443 (59.54)	**<0.001***
Elective CS	50 (22.03)	86 (39.81)	136 (30.70)	
Emergency CS	177 (77.97)	130 (60.19)	307 (69.30)	
Labour Onset (n=465)				
Spontaneous Labour	202 (89.38)	227 (94.98)	429.7 (92.26)	**0.024***
Induction of Labour	24 (10.62)	12 (5.02)	36 (7.74)	
Induction Methods (n=27)				
Oral Misoprostol	11 (64.71)	8 (80.00)	19 (70.37)	0.233
Vaginal Prostaglandin	1 (5.88)	2 (20.00)	3 (1.11)	
Intravenous Oxytocin	4 (23.53)	0 (0.00)	4 (14.81)	
Foley's Catheter	1 (5.88)	0 (0.00)	1 (3.70)	
Augmentation of Labour (n=40)				
Oxytocin	18 (8.33)	19 (7.95)	3 (8.13)	0.881
Successful augmentation	9 (50.00)	7 (36.84)	16 (43.24)	0.419
Unsuccessful augmentation	9 (50.00)	12 (63.16)	21 (56.76)	
Partogram Use (n=326)				
Adequate 2 hourly plot	104 (80.62)	170 (86.73)	274 (84.31)	0.138
Inadequate 2 hourly plot	25 (19.38)	26 (13.27)	51 (15.69)	
Foetal Monitoring (n=744)				
EFM done	295 (79.30)	311 (83.60)	606 (81.45)	0.131
EFM not done	77 (20.70)	61 (16.40)	138 (18.55)	
[b]EFM Category (n=597)				
Unsigned Trace	53 (18.21)	63 (20.59)	116 (19.43)	**0.026***
Cat1/Reassuring/Reactive	126 (43.30)	160 (52.29)	286 (47.91)	
Category 2/Suspicious/Non-Reassuring	58 (19.93)	47 (15.36)	105 (17.59)	
Category 3/Abnormal/Pathological	54 (18.56)	36 (11.76)	90 (15.08)	
Delivering Healthcare Worker (n=744)				
Not applicable (BBA/Unknown)	29 (7.80)	18 (4.84)	47 (6.32)	
Midwife	99 (26.61)	134 (36.02)	233 (31.32)	**<0.001***
Intern doctor	11 (2.96)	3 (0.81)	14 (1.88)	
Community Service doctor	17 (4.57)	68 (18.28)	85 (11.42)	
Registrar doctor	216 (58.06)	149 (40.05)	365 (49.06)	
Delivery Difficulty (n=744)				
No Delivery Difficulty	352 (94.62)	361 (97.04)	713 (95.83)	0.101
Documented Delivery Difficulty	20 (6.13)	11 (3.40)	31 (4.77)	

BBA: Born Before Arrival, CS: Caesarean Section, EFM Electronic Foetal Monitoring, NVD: Normal Vaginal Delivery, NNM: Neonatal Near Miss, [a]Pearson's chi-square analysis, [b]EFM was documented in 9 cases to have been done however, CTGs were not in files for analysis. Thus n=597, *P-value <0.05

Table 3: Univariable and multivariable logistic regression of maternal factors of neonatal near miss.

Factors regression	Univariable logistic			Multivariable logistic regression		
	OR	95% CI	P-value	OR	95% CI	P-value
Age (Years)						
20-34	1.00	Ref	Ref	1.00	Ref	Ref
Teenage Pregnancy (≤19)	1.60	0.88-2.90	0.122	0.61	0.12-3.13	0.555
Advanced Maternal Age (≥35)	2.01	1.32-3.05	0.001*	2.65	1.10-6.41	0.029*
Race						
White	1.00	Ref	Ref	1.00	Ref	Ref
Black	0.48	0.39-2.55	1.000	1.01	0.18-5.52	0.991
Coloured	0.64	0.42-3.41	0.732	1.21	0.16-8.95	0.850
Indian/Asian	0.38	0.14-2.12	0.382	0.67	0.06-7.20	0.741
Social Habits						
No Habits	1.00	Ref	Ref	1.00	Ref	Ref
Habits	2.61	1.43-4.75	**0.002***	4.48	1.54-13.05	**0.006***
Parity						
Nulliparous	1.00	Ref	Ref	1.00	Ref	Ref
Multiparous	0.87	0.64-1.20	0.453	0.62	0.33-1.12	0.145
BMI						
19.9-24.9 (normal)	1.00	Ref	Ref	1.00	Ref	Ref
≤19.8 (underweight)	2.76	1.09-6.99	**0.033***	4.40	1.22-15.80	**0.023***
≥25 (Increased BMI)	1.24	0.79-2.00	0.352	1.13	0.58-2.19	0.724
HIV Status						
Negative	1.00	Ref	Ref	1.00	Ref	Ref
Positive	0.84	0.58-1.22	0.361	0.56	0.26-1.18	0.128
Unknown	1.04	0.61-1.77	0.891	1.79	0.50-6.48	0.373
Delivery Gestational Age						
38-40+6 weeks	1.00	Ref	Ref	1.00	Ref	Ref
≤33+6	10.41	6.51-16.64	**<0.001***	4.56	1.92-10.83	**0.001***
34-37+6	1.87	1.26-2.76	**0.002***	1.35	0.68-2.67	0.394
≥41	1.64	0.63-4.27	0.309	0.72	0.16-3.23	0.663
Chronic Medical Disorder						
No disorders	1.00	Ref	Ref	1.00	Ref	Ref
Chronic d/o present	2.16	1.09-4.26	**0.026***	0.52	0.11-2.46	0.406
Antenatal Pregnancy Specific Disorder						
No Antenatal disorder	1.00	Ref	Ref	1.00	Ref	Ref
Antenatal disorder developed	6.08	4.34-8.50	**<0.001***	5.19	2.61-10.30	**<0.001***
Delivering Healthcare Worker						
Midwife	1.00	Ref	Ref	1.00	Ref	Ref
Intern	4.96	1.35-18.26	**0.016***	44.7	2.27-880.06	**0.012***
Community Service	0.34	0.19-0.61	**<0.001***	0.44	0.81-2.39	0.341
Registrar	1.96	1.40-2.74	**<0.001***	5.91	1.61-21.74	**0.008***
Delivery Type						
Vaginal/BBA	1.00	Ref	Ref	1.00	Ref	Ref
Emergency CS	1.46	1.06-2.02	**0.019***	0.19	0.05-0.69	**0.012***
Elective CS	0.63	0.41-0.95	**0.027***	0.22	0.06-0.88	**0.032***
Employment						
Unemployed	1.00	Ref	Ref			
Employed	0.74	0.54-1.01	0.056			
Booking Status						
Booked ≤13+6/40	1.00	Ref	Ref			

Booked ≥14/40	1.18	0.73-1.90	0.510
Unspecified/Unbooked	2.50	1.14-5.47	**0.022***
Booking Hb			
Normal (≥11)	1.00	Ref	Ref
Anaemic (≤10.9)	0.89	0.65-1.23	0.491
Untested	3.30	1.73-6.32	**<0.001***
Labour Onset			
Spontaneous Labour	1.00	Ref	Ref
Induction of Labour	2.25	1.10-4.61	**0.027***
EFM Category			
Category1/Reassuring/Reactive	1.00	Ref	Ref
Category2/Suspicious/Non-Reas	1.57	1.00-2.46	0.050
Category3/Abnormal/Pathological	1.93	1.18-3.13	**0.008***
Unsigned Trace	1.03	0.66-1.59	0.896
History of TOP			
No TOP	1.00	Ref	Ref
Previous TOP	1.86	1.11-3.11	**0.018***
Previous Caesarean Section			
1 Previous CS	1.00	Ref	Ref
2 Previous CS	0.90	0.44-1.83	0.769
≥3 Previous CS	4.29	0.43-42.42	0.213
Gestation Type	1.00	Ref	Ref
Singleton			
Multiple	6.91	2.66-17.93	**<0.001***
Antenatal visits	1.00	Ref	Ref
≥3 visits			
≤2 visits	6.91	2.66-17.93	**0.019***
Antenatal Risk Classification	1.00	Ref	Ref
Low			
Medium	1.32	0.88-2.00	0.183
High	1.74	1.10-2.77	**0.018***
Unclassified	1.42	0.96-2.08	0.077
RPR Status	1.00	Ref	Ref
Non-Reactive			
Reactive	2.59	0.50-13.43	0.258
Unknown	1.53	0.84-2.78	0.168
Rh group			
Positive	1.00	Ref	Ref
Negative	1.27	0.50-3.26	0.617
Unknown	1.60	0.61-4.17	0.338
Partogram Use Adequacy	1.00	Ref	Ref
Adequate 2 hourly plot			
Inadequate 2 hourly plot	1.57	0.86-2.87	0.140
Electronic Foetal Monitoring	1.00	Ref	Ref
EFM done			
EFM not done	1.36	0.94-1.98	0.107
Reported Difficulties with Delivery		Ref	Ref
No difficulty reported	1.00		
Difficulty reported	1.86	0.88-3.95	0.106

MAJOR NEONATAL NEAR MISS RISK PATIENT FACTORS

Sociodemographic Factors	**Antenatal Factors**	**Delivery Factors**
Advanced maternal age	Underweight BMI	Induction of labour
Smoking/alcohol/drugs	Pathological trace	Intern delivery
Previous TOP	Gestational age ≤33+6	Registrar delivery

Pregnancy specific disorder	Community Service doctor delivery**
Unbooked	Elective CS**
Medical/Pregnancy disorder	Emergency CS**
Multiple pregnancy	

BBA: Born Before Arrival, BMI: Body Mass Index, CS: Caesarean Section, EFM: Electronic Foetal Monitoring, Habit includes alcohol ingestion, smoking and illicit drug use. Hb: haemoglobin, Non-Reas: Non-reassuring, NVD: Normal Vaginal Delivery, Rh: Rhesus, RPR: Rapid Plasma Reagin, HIV: Human immunodeficiency virus, TOP: Termination of Pregnancy, *P-value <0.05, **indicates a protective association.

Emergency caesarean section was associated with an 81% decrease in NNM (OR=0.19, 95% CI: 0.05-0.69, P<0.012).

Discussion

Neonatal near miss is a valuable contemporary method for assessing the quality of obstetric and neonatal healthcare services[5–7]. This study was therefore conducted to assess the NNM rate and associated sociodemographic and obstetric factors at a large public mother and child hospital in Johannesburg, Gauteng Province, South Africa. The neonatal miss rate in this study was 110 per 1000 births with an NNM: PMR ratio of 3.6:1. Multiple obstetric factors were identified to be associated with NNM. Advanced maternal age (≥ 35 years) was significantly more prevalent in the NNM group. Furthermore, the study found over two-fold increase in NNM among women with advanced age on multivariable regression analysis. This finding is in line with the report of Mersha *et al*[9], who also reported an association between advanced maternal age and NNM. This is however in contrast with that of de Lima *et al*, who found advanced maternal age to be protective against NNM[10]. Advanced maternal age is associated with pregnancy complications such as hypertensive disorders, diabetes mellitus, large for gestational age, foetal growth restriction, preterm birth, dysfunctional labour, leiomyomata in pregnancy, multiple gestation, congenital anomalies, placenta previa and abruptio, and caesarean section delivery[11,12]. Thus, women with advanced maternal age should be considered high-risk and monitored closely to reduce the risk of developing NNM.

Furthermore, mothers who had non-sober social habits such as smoking, alcohol use or illicit drug use, had an approximately 4-fold likelihood of having a baby with NNM when compared to those with sober habits. The above agrees with a study by Kale *et al*, that was conducted among a Brazilian population[13]. Smoking is associated with an increased risk of foetal growth restriction, placenta previa and abruptio placenta[14]. This study also found that alcohol was associated with reduced weight and length of the neonate and cocaine use, with preterm delivery and reduced foetal head circumference. The above could result in the development of severe neonatal morbidity, which manifests as NNM.

There was no statistically significant difference in the risk of having NNM between primigravid and multiparous patients. This finding differs from those of de Lima[10] and Mersha *et al*[11], who found multiparous patients to be at increased risk of NNM. The above could be explained by the higher incidence of unbooked status, hypertensive disorders of pregnancy, intrauterine growth restriction (IUGR), oligohydramnios, and consequently preterm deliveries, low birth weight, oligohydramnios, and emergency caesarean section delivery, all of which are associated with adverse neonatal outcomes[15].

Furthermore, mothers who were underweight had increased risk of NNM. NNM was about four-fold more prevalent amongst underweight women as compared to those with normal weight. Whilst most of the literature reports that maternal obesity contributes to poor neonatal outcomes, our study suggests that underweight also increases the risk of NNM. This finding is supported by existing literature[16]. Although emphasis should be placed on counselling women regarding the deleterious impact of obesity and the need to lose weight, intervention should also be undertaken to assist underweight women to achieve normal weight. Medical conditions, such as hypertension and diabetes mellitus are co morbidities known to be associated with NNM[2,10,11,14]. Our study suggests that the development of any medical or pregnancy specific disorder during the pregnancy carries a higher risk for the development of neonatal near misses than that of a chronic disorder. We postulate that levels of control of chronic disorders are high in our population whilst new disorders arising during

pregnancy might have increased the risk of NNM due to delays between diagnosis and management, given the high rate of overcrowding and shortage of staff at the study site. Induction of labour doubled the risk of NNM when compared to spontaneous labour. This is in keeping with the findings of a large Austrian cohort study. This study concluded that induction of labour increases the risk of poor neonatal outcomes[17]. Assessment of indications for induction of labour and the appropriateness of intrapartum care could shed more insight regarding this finding as the observation could be due to the indication of induction of labour rather than the procedure itself. The use of partogram was adequate in most cases. There were insignificant differences in neonatal outcomes when not used adequately. Whilst poor progress of labour and the lack of partogram use may be clinically relevant and expected to influence neonatal outcome, no significant difference was found between the two groups.

Elective caesarean section delivery was associated with a reduction in the risk of neonatal near miss. In univariable logistic regression analysis, emergency caesarean section was linked to a 46% increase in NNM. However, multivariable regression analysis indicated a reduction in the risk of NNM associated with emergency caesarean section. These findings could suggest that emergency caesarean section is associated with an increased risk of NNM in the presence of other NNM risk factors. These findings also suggest that elective caesarean section should be the preferred mode of delivery, when there is a need, to avoid foreseeable NNM in high-risk patients. Benzounia *et al* also reported that emergency caesarean section had a higher rate of poor foetal outcomes when compared to elective caesarean section[18]. Once again, the indication for an emergency caesarean section, rather than the procedure itself, may be the reason behind the increased risk of NNM.

A delivery conducted by a registrar had an almost six-fold increased odds in NNM rates. This was expected since difficult and high-risk deliveries are often managed by registrar doctors at the study site. On the other hand, deliveries by interns are expected to be among low-risk pregnancies. However, inexperience might have led to a very high odds of NMM (up to 44 folds) among the few deliveries (n=14) conducted by this group of healthcare providers. This is due to a significant shortage of staff at the study site, which often results in registrars being in the operating theatre, leaving interns and midwives to manage the labour ward.

A finding that is difficult to explain is the finding of an association between a history of previous pregnancy termination of pregnancy (TOP) with NNM. Our study found an almost two-fold odds increased risk of NNM among women who had previous TOP. A recent study in South Ethiopia showed that 9.4% of women with NNM had a history of one or more TOP[19]. While the reason is not clear, the above suggests that patients who have undergone TOP may be considered at risk of a poor neonatal outcomes. Further research regarding the association of TOP and subsequent pregnancy NNM can help to clarify this finding. The association between HIV and NNM is not well documented. However, HIV infection and antiretroviral treatment (ART) use has been associated with adverse pregnancy outcomes such as preterm delivery, low birth weight and pre-labour rupture of membranes, among others[20]. It is expected that such adverse outcomes can increase the risk of NNM. Surprisingly, HIV infection was not found to be associated with increased risk of NNM among the our study cohort. This contrasts with another study that found significant risk for cerebral palsy.

Maternal Health in South Africa is significantly affected by the HIV epidemic[21]. Our result may suggest that the concerted public health and obstetric interventions such as widescale HIV testing, expansion of ART access and obstetric prevention of mother to child transmission strategies, might have reduced the incidence of HIV associated adverse pregnancy outcomes. Furthermore, it is likely that most HIV positive patients presented with suppressed and undetectable viral loads before pregnancy. A further study is required to validate this finding. We found that there was no statistically significant association between ethnicity or employment status and NNM. This contrasts with another study which found statistical differences, noting that ethnicity and employment status may be a surrogate for socio-economic status[22]. Educational level which is commonly assessed in literature is not regularly documented in our antenatal files and thus was not assessed in our study. The same study reported that disparities in obstetric outcome exist not only in differing income and education groups, but also in racial groups of

similar education status A Brazilian cross-sectional study found that race and ethnicity were not statistically significantly associated with NNMs. The researchers concluded that poorer socioeconomic status, access to healthcare services, and lower education levels should be the primary focus of research in evaluating risks for adverse outcomes rather than race and ethnicity[23].

Our findings may be attributed to the characteristics of our study site, which is a public hospital primarily serving low- and middle-income women. Additionally, the majority of women accessing care at this hospital are historically Black and Coloured. Consequently, race and ethnicity may have a limited impact on outcomes at the hospital due to the population's homogeneity. In South Africa, patients from higher socio-economic backgrounds are more likely to seek care at private hospitals. Furthermore, studies indicate that White patients have the lowest likelihood of utilizing public healthcare services compared to other racial groups[24].

Strengths and limitations.

The findings of this study should be considered within the context of its limitations. While the study is replicable, it employed a definition of NNM that may be subjective and subject to variation based on the criteria utilized by different institutions. Additionally, a potential issue related to the definition of NNM in our study is the possibility of selection bias, which may have resulted from including preterm gestations of less than <33+6 and birth weight <1750g. These pragmatic criteria were used by Pileggi-Castro *et al*[4] and thus adopted by our study. Delivery gestation of <33+6 and birth weight <1750g do not necessarily translate into morbidity or a poor outcome, although they were used in the defining criteria for NNM.

Some variables, such as labor duration, were not explicitly recorded in the available documentation. Additionally, data on CD4 counts and viral loads for HIV-positive patients would have been collected from the mothers in a prospective study. However, due to the retrospective nature of this study, thorough filing and documentation were not guaranteed. Consequently, bias may have been introduced by excluding poorly documented files from the analysis. Despite these limitations, the study has several strengths. A notable strength is the relatively large sample size, which provided sufficient power for the analysis and minimized the risk of Type II error. The population was a random sample of patients served by the study site, making the findings truly representative of the catchment population. Furthermore, several potential maternal explanatory variables were evaluated.

With obstetric factors identified as markers for neonatal near misses, further research is warranted to determine whether a cumulative effect exists among these factors regarding the risk of NNM. Strategies aimed at enhancing modifiable obstetric factors associated with NNM should also be explored with specific focus on reducing NNM rates. We recommend integrating NNM into broader clinical practice and patients exhibiting any identified NNM risk factors should be referred to higher levels of care equipped with the necessary skills and resources to manage near-miss outcomes.

Conclusions

This study provides valuable insights into neonatal near misses and associated maternal socio-biological and pregnancy factors, which are similar to those reported in perinatal deaths. This underscores the need for increased vigilance, counselling for at-risk women, and the development of protocols to improve management of at risk pregnancies and complications during pregnancy. Furthermore, we advocate for the routine assessment of near misses to improve the quality of care and reduce pregnancy-related losses and complications.

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Authors contributions

CM and LC conceived the study. CM, LC, FN and GO assisted in study design and proposal development. CM and JF were involved with data collection. CM and GO performed analysis. CM wrote the original manuscript. LC reviewed and revised the final manuscript. All authors read, edited and approved the final manuscript.

Conflict of interest

All the authors have no conflicts of interest.

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