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MATERNAL-FETAL MEDICINE

Adverse perinatal outcomes are associated with severe maternal morbidity and mortality: evidence from a national multicentre cross-sectional study

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Abstract

Purpose To assess the association between maternal potentially life-threatening conditions (PLTC), maternal near miss (MNM), and maternal death (MD) with perinatal outcomes.

Methods Cross-sectional study in 27 Brazilian referral centers from July, 2009 to June, 2010. All women presenting any criteria for PLTC and MNM, or MD, were included. Sociodemographic and obstetric characteristics were evaluated in each group of maternal outcomes. Childbirth and maternal morbidity data were related to perinatal adverse outcomes (5th min Apgar score < 7, fetal death, neonatal death, or any of these). The Chi-squared test evaluated the differences between groups. Multiple regression analysis adjusted for the clustering design effect identified the independently associated maternal factors with the adverse perinatal outcomes (prevalence ratios; 95% confidence interval).

Results Among 8271 cases of severe maternal morbidity, there were 714 cases of adverse perinatal outcomes. Advanced maternal age, low level of schooling, multiparity, lack of prenatal care, delays in care, preterm birth, and adverse perinatal outcomes were more common among MNM and MD. Both MNM and MD were associated with Apgar score (2.39; 1.68–3.39); maternal hemorrhage was the most prevalent characteristic associated with fetal death (2.9, 95% CI 1.81–4.66) and any adverse perinatal outcome (2.16; 1.59–2.94); while clinical/surgical conditions were more related to neonatal death (1.56; 1.08–2.25).

Conclusion We confirmed the association between MNM and MD with adverse perinatal outcomes. Maternal and perinatal issues should not be dissociated. Policies aiming maternal care should include social and economic development, and improvements in accessibility to specialized care. These, in turn, will definitively impact on childhood mortality rates.

Keywords Perinatal morbidity · Perinatal mortality · Severe maternal morbidity · Maternal near miss · Maternal mortality · Apgar score

Abbreviations

LB	Live births
CI	Confidence interval
LMIC	Low- and middle-income countries
MD	Maternal death
MDG	Millennium development goals
MNM	Maternal near miss
PLTC	Potentially life-threatening condition
PR	Prevalence ratio
SMM	Severe maternal morbidity
SMO	Severe maternal outcomes
WHO	World Health Organization

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Introduction

The deadline for the millennium development goals (MDG) was completed in 2015. This would mean a reduction in child mortality from 12 million, in 1990, to

less than 4 million, in 2015 [1]. Although infant mortality has significantly dropped in the last 25 years worldwide, 16,000 children still die every day from preventable causes [2]. Therefore, infant mortality is still a challenge and remains on the new agenda of sustainable development [2]. The neonatal deaths—that represent 40% of all infant mortality worldwide—have decreased more slowly than that of children aged 1–5 years [2, 3]. The first day, week, and month of life are of critical importance for child survival. Major causes of neonatal deaths include preterm births, complications during labor and delivery, and sepsis [2]. These could be prevented by simple, cost-effective, high-impact interventions, if targeted at mothers and newborn infants, particularly near the childbirth period [2, 3].

In Brazil, there has been a striking reduction in childhood mortality in recent decades, and neonatal deaths account for 68% of the child mortality. Brazil is among the ten countries with the highest absolute number of infant deaths, but neonatal mortality has shown a slow decline [3–6]. At the same time, it is widely known that neonatal morbidity and mortality are closely associated with the care provided to women during pregnancy and childbirth. Identifying any possible failure or delay in maternal care is an effective strategy for planning appropriate intervention. Furthermore, it is also likely that the occurrence of obstetric complications may play a crucial role in determining adverse perinatal outcomes. Despite the lack of definitive national data to support this assumption, a large international study has demonstrated a strong association between the occurrence of all types of maternal near miss and early neonatal mortality [7]. Surveys from Uganda [8] and Côte d'Ivoire [9] also highlight the association between obstetric complications and perinatal morbidity and mortality, especially when there is maternal hemorrhagic, hypertensive, or infectious disorder.

This is a secondary analysis from a national multicentre study for severe maternal morbidity (SMM) surveillance, including maternal near miss (MNM) and maternal mortality in Brazil [10–12]. The aim of the present study is to evaluate the association between obstetric complications and adverse perinatal outcomes in Brazil.

Methods

The Brazilian Network for Surveillance of Severe Maternal Morbidity was a cross-sectional multicentre study conducted in 27 referral maternity hospitals from different regions of Brazil. The study was funded by the Brazilian National Research Council (CNPq); the research protocol and methodological details for network implementation were previously published [10–12]. This report follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [13].

Briefly, during a 12-month period (July, 2009–June, 2010), trained researchers collected data from each participating center to identify severe maternal morbidity (potentially life-threatening conditions, PLTC, and MNM) and maternal deaths (MD), following the World Health Organization's criteria [14]. Sociodemographic (maternal age, marital status, schooling, ethnicity, parity, and prenatal care) and obstetric characteristics (financial coverage for childbirth, gestational age at delivery, onset of labor, mode of delivery, and any delay in obtaining obstetric care) of women, and perinatal variables (vitality status at birth, Apgar score at 1st and 5th min, infant sex, fetal presentation, birthweight and neonatal outcome) were retrieved from medical charts after hospital discharge or death. Data were entered into a real-time electronic database, using the OpenClinica® platform, version 3.0 (https://www.openclinica.com/), which is specific for clinical studies [11]. In this manuscript, we report data from all pregnancies; please refer to Santana et al. [15] for data on multiple pregnancies.

The research proposal was initially approved by the Institutional Review Board of each participating institution and the Brazilian National Council of Research Ethics (letter of approval 097/2009 from 5th March 2009). Then, local investigators and coordinators were trained by the central coordinating team; simulations were run to enter the collected data into the electronic system. To minimize bias and to ensure data collection uniformity, a standardized operation manual was provided. Additionally, according to the study protocol, each local coordinator collected, reviewed, and registered information of eligible cases into the system. Subsequently, the local investigator checked data consistency, and amended any missing data [11, 12]. During the study period, coordinating researchers visited participating centers for monitoring purposes. At each visit, approximately 5% of the cases were randomly selected to check for data consistency: data previously registered were compared to patient information available in the medical charts.

Statistical analysis

The study population consisted of all women admitted to participating centers during the study period. Sample size was calculated considering an alfa error of 5%, and approximately 600 cases of maternal near miss and 100 cases of maternal deaths. An estimated rate of eight maternal near miss cases/1000 births was applied, indicating the need to evaluate at least 75,000 births [16]. The main outcome was the adverse perinatal result, defined as: intrautero fetal death, Apgar score < 7 at the 5th min of life, neonatal death (up to the 28th day of life, evaluated till hospital discharge), or any of these. A cutoff of 2500 g characterized low birthweight [17].

The distribution of cases among different categories of morbidity (PLTC, MNM, and MD) was initially evaluated—according to maternal and newborn characteristics—and presented as absolute numbers and percentages. Then, analysis of stratified data was performed, evaluating the proportions of different adverse perinatal outcomes among distinct categories of gestational age, birthweight, mode of delivery, and determining cause of SMM. Possible differences among groups were evaluated by the Chi-squared test (Yates correction), with the respective values of statistical significance (p value) adjusted for clustering design effect. Missing information is informed in the footnote of each table. Finally, using the Poisson multiple regression analysis, all predictive variables independently associated with the adverse perinatal outcomes were identified, estimating the prevalence ratio (PR) and their respective 95% confidence interval (CI): the Model 1 evaluated fetal death; Model 2, low 5th min Apgar score; Model 3, neonatal death and Model 4, any adverse perinatal outcome. We considered, as predictors: age (years); ethnicity (white × non-white); schooling (up to primary × high or superior); marital status (with × without partner); parity (primiparous × non primiparous); number of antenatal contacts ($<6\ x \geq 6$); financial coverage for delivery (public × any other); gestational age at delivery (weeks); onset of labor (no onset × spontaneous or induced); mode of delivery (vaginal × cesarean); fetal presentation (cephalic × any other); birthweight (kg); any delay in obstetric care (yes × no) [18]; SMM (MNM or MD versus PLTC); hemorrhage (yes × no), hypertension (yes × no), infection (yes × no), or clinical/surgical disorders (yes × no) as diagnosis of SMM [14].

All statistical procedures were performed with the Statistical Package for the Social Sciences (IBM SPSS®, Armonk, NY, USA) for Windows, version 23.0, and the Stata, (StataCorp, College Station, TX, USA), version 11.2. A p value <0.05 was considered for significance.

Results

During the study period, a total of 82,388 women were admitted to the participating centers for any pregnancy-related condition, resulting in 82,144 live births. SMM were identified in 9555 women (11.6%), and perinatal data were available for 8271 of them (86.5%). Of the 737 severe maternal outcome (SMO) [11] cases, there were 624 MNM and 113 MD (Fig. 1). Regarding perinatal results, there were 374 fetal deaths (4.5%), 286 infants with 5th min Apgar score < 7 (3.4%), and 181 neonatal deaths (2.3% of live births).

All the studied maternal variables were statistically associated with increasing SMM severity, except ethnicity, type of onset of labor, and mode of delivery (Table 1). Maternal age over 30 years, lower level of schooling, multiparity, and lack of prenatal care were significantly more common in the MNM and MD groups of women. Among women experiencing the worst outcome, the proportion of those who did not receive prenatal care increased twofold in women with MNM and MD (6.7 and 5.3%, respectively) when compared to those with PLTC (3%).

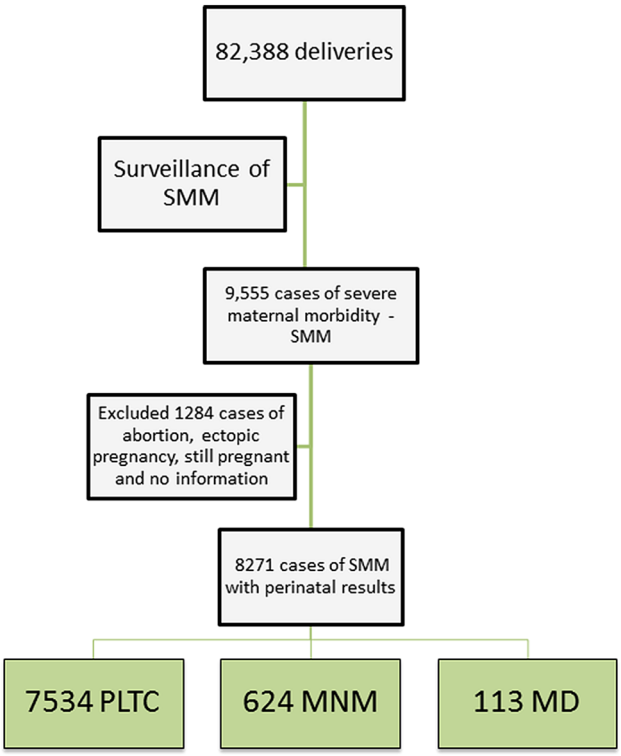

Fig. 1 Flowchart of subjects in the study. *SMM* severe maternal morbidity, *PLTC* potentially life-threatening condition, *MNM* maternal near miss, *MD* maternal death

Gestational age at birth < 37 weeks and delays in receiving obstetric care (Table 1) were also statistically associated with the increasing maternal morbidity severity ($p<0.001$): 73.4% and 82% of MD evolved with preterm births and delays, respectively. Proportions of adverse perinatal outcomes, and of 1st min Apgar score < 7 and low birthweight as well, were progressively greater with increasing severity of maternal illness ($p<0.001$) (Table 2). The higher prevalences were observed among the MD cases, in which 31% corresponded to fetal or neonatal deaths.

In Table 3, the adverse perinatal outcomes are presented according to the childbirth characteristics; all of them were significantly associated with the gestational age (< 34 weeks) and low birthweight. Vaginal delivery was more common only in fetal death (51.3%). Neonatal death was not associated with any obstetric complications. Maternal hemorrhage was associated with all the remaining adverse outcomes, while maternal hypertension was only associated with low Apgar score at the 5th min.

Table 1 Sociodemographic, obstetric, and delivery characteristics of women according to the severity of maternal complication

Characteristics	PLTC, *N* (%)	MNM, *N* (%)	MD, *N* (%)	*p* value*
Maternal age (years)				
10–19	1428 (19.0)	90 (14.4)	19 (16.8)	**0.004**
20–29	3619 (48.0)	267 (42.8)	53 (46.9)	
30–39	2152 (28.6)	222 (35.6)	33 (29.2)	
40–49	335 (4.4)	45 (7.2)	8 (7.1)	
Marital status[a]				
With partner	3399 (52.1)	336 (67.6)	55 (64.0)	**0.002**
Without partner	3119 (47.9)	161 (32.4)	31 (36.0)	
Schooling[b]				
None/primary	2649 (46.0)	212 (52.2)	28 (50.0)	**0.004**
High	2802 (48.7)	152 (37.4)	25 (44.6)	
University	304 (5.3)	42 (10.3)	3 (5.4)	
Ethnicity[c]				
White	2283 (40.5)	253 (51.1)	47 (50.5)	0.073
Non-white	3354 (59.5)	242 (48.9)	46 (49.5)	
Parity[d]				
0	3853 (51.3)	228 (36.9)	48 (44.0)	**< 0.001**
1–2	2758 (36.7)	270 (43.7)	44 (40.4)	
≥ 3	902 (12.0)	120 (19.4)	17 (15.6)	
Prenatal care (visits)[e]				
No	185 (3.0)	28 (6.7)	4 (5.6)	**< 0.001**
1–5	2269 (37.3)	185 (44.4)	39 (54.2)	
≥ 6	3636 (59.7)	204 (48.9)	29 (40.3)	
Financial coverage of delivery				
Public	7456 (99,0)	605 (97.0)	110 (98.2)	**0.007**
Private/health insurance	73 (1.0)	19 (3.0)	2 (1.8)	
Gestational age at delivery[f]				
< 34	1436 (19.5)	203 (37.9)	38 (40.4)	**< 0.001**
34–36	1619 (22.0)	130 (24.3)	31 (33.0)	
≥ 37	4292 (58.4)	202 (37.8)	25 (26.6)	
Onset of labor[h]				
Spontaneous	2504 (33.5)	170 (28.5)	34 (31.8)	0.376
Induced	756 (10.1)	54 (9.0)	9 (8.4)	
No labor	4214 (56.4)	373 (65.2)	64 (59.8)	
Mode of delivery				
Vaginal	1966 (26.1)	128 (20.5)	29 (25.7)	0.228
C-section	5568 (73.9)	496 (79.5)	84 (74.3)	
Any delay in obstetric care[i]				
Yes	3612 (52.4)	383 (67.2)	82 (82.0)	**< 0.001**
No	3276 (47.6)	187 (32.8)	18 (18.0)	
Total	7534	624	113	8271

Values in bold mean they are statistically significant

PLTC potentially life-threatening condition, *MNM* maternal near miss, *MD* maternal death

*Yates correction for the χ^2 test; *p* values adjusted for the clustering design effect

Missing information: [a]1170; [b]2054; [c]2046; [d]31; [e]1692; [f]6; [g]295; [h]93; [i]713 cases

Table 4 demonstrates the four regression models for independently associated factors to the adverse perinatal outcomes. In general, sociodemographic characteristics were not associated with the adverse perinatal outcomes, except a higher maternal age (PR 1.03; 95% CI 1.01–1.06; Model 1) and marital status (PR 1.18; 95% CI 1.01–1.37; Model 4). The mode of delivery was only associated with fetal death (PR 2.88; 95% CI 1.87–4.44). The presence

Table 2 Perinatal results according to type and severity of maternal complication

Perinatal results	PLTC, *N* (%)	MNM, *N* (%)	MD, *N* (%)	*p* value*
Status at birth				
Alive	7155 (96.4)	478 (85.8)	70 (71.4)	< **0.001**
Fetal death	267 (3.6)	79 (14.2)	28 (28.6)	
1st min Apgar score[b] < 7	1347 (19.0)	168 (37.8)	37 (56.9)	< **0.001**
5th min Apgar score[c] < 7	219 (3.1)	46 (10.3)	21 (32.3)	< **0.001**
Male newborn[d]	3641 (49.7)	255 (48.8)	44 (51.2)	0.799
Fetal presentation[e]				
Cephalic	6211 (91.7)	409 (86.3)	77 (90.6)	**0.001**
Breech	489 (7.2)	54 (11.4)	6 (7.1)	
Other	72 (1.1)	11 (2.3)	2 (2.4)	
Birthweight[f]				
< 2500 g	2781 (38.1)	292 (57.7)	57 (67.1)	< **0.001**
2500–3999 g	4195 (57.4)	208 (41.1)	28 (32.9)	
≥ 4000 g	328 (4.5)	6 (1.2)	0 (0.0)	
Neonatal outcome[g]				
Alive	5305 (76.9)	276 (61.1)	32 (47.8)	< **0.001**
Alive with problem	1441 (20.9)	158 (35.0)	28 (41.8)	
Neonatal death	156 (2.3)	18 (4.0)	7 (10.4)	
Total	7534	624	113	8271

Values in bold mean they are statistically significant

PLTC potentially life-threatening condition, *MNM* maternal near miss, *MD* maternal death

*Yates correction for the χ^2 test; *p* values adjusted for the clustering design effect

Missing information for: [a]194; [b]662; [c]668; [d]338; [e]940; [f]376; [g]850 cases

of MNM or MD, compared to PLTC, was more than 2.5 times higher in fetal death (Model 1) and low Apgar score cases (Model 2), and 85% more prevalent when considering any perinatal outcome. Delays in obstetric assistance and maternal hemorrhage were associated with all the outcomes, but more strongly to fetal death (PR of 1.96 and 2.90, respectively). For neonatal death, the main associated variable was clinical or surgical obstetric cause for SMM (PR 1.56). A higher birthweight (all four Models), being in cephalic presentation (Models 1, 2, and 4), the absence of labor (Models 1, 2, and 4), and a more advanced gestational age at birth (Models 2, 3, and 4), decreased the risk of unfavorable perinatal outcomes.

Discussion

This multicentre cross-sectional study reinforces the clear association between SMM and adverse perinatal outcomes. The perinatal conditions addressed are linked to hemorrhagic, hypertensive, infectious or clinical/surgical complications, when analyzed separately or in combination. Therefore, we confirm the hypothesis that maternal and infant health should be perceived as a unit.

In low- and middle-income countries (LMIC), MNM and MD remain related to poor socioeconomic development [8, 9, 19, 20], as we corroborated that low and advanced maternal age, low level of school education, lack of antenatal visits, and higher parity were more frequently found in these women. In 2013, the maternal death ratio was 230/100,000 livebirths in LMIC, against 16/100,000 in high-income countries [21]. Over 250,000 women lost their lives in 2013 due to unpreventable conditions or complications at the time of childbirth. Unfortunately, despite all the efforts to achieve the 5th MDG in the past years, the aim was not attained worldwide; Latin America has decreased by 40% in the maternal mortality ratio [2], which was estimated as 60/100,000 in 2015 [22, 23]. The World Health Organization (WHO) considers these high maternal mortality ratios as unacceptable, which uncovers important social disparities, such as pregnancy in extremes of age [20] and unequal access to antenatal and delivery care—by skilled professionals—between women from urban and rural areas [2].

In fact, as observed by other authors, pregnant women living in rural settings, with low level of education or improper access to health care, have worse obstetric outcomes than those living in urban regions [8, 9, 18, 19, 24]. Although we

Table 3 Characteristics of birth according to adverse perinatal outcomes

Characteristics	Adverse perinatal outcomes*			
	Fetal death	5th min Apgar < 7	Neonatal death	Any adverse perinatal outcome
Gestational age at birth				
< 34 weeks	214 (64.3)	163 (58.4)	150 (85.2)	464 (65.0)
34–36 weeks	69 (20.7)	63 (22.6)	11 (6.2)	137 (19.2)
≥ 37 weeks	50 (15.0)	53 (19.0)	15 (8.5)	113 (15.8)
	< 0.001	**< 0.001**	**< 0.001**	**< 0.001**
Birthweight				
< 2500 g	239 (84.5)	209 (74.4)	157 (90.2)	540 (81.1)
2500–3999 g	40 (14.1)	68 (24.2)	17 (9.8)	118 (17.7)
≥ 4000 g	4 (1.4)	4 (1.4)	0 (0.0)	8 (1.2)
	<0.001	**<0.001**	**<0.001**	**<0.001**
Mode of delivery				
Vaginal	192 (51.3)	58 (20.3)	33 (18.2)	260 (34.0)
C-section	182 (48.7)	228 (79.7)	148 (81.8)	505 (66.0)
	<0.001	0.314	0.196	0.090
Main determining cause of SMM				
Hemorrhage	170 (45.5)	98 (34.3)	48 (26.5)	289 (37.8)
	<0.001	**0.01**	0.248	**0.01**
Hypertension	252 (67.4)	196 (68.5)	132 (72.9)	528 (69.0)
	0.090	**0.019**	0.357	0.107
Infection	9 (2.4)	2 (0.7)	2 (1.1)	13 (1.7)
	0.004	0.308	0.152	**0.001**
Clinical/surgery	31 (8.3)	27 (9.4)	13 (7.2)	65 (8.5)
	0.252	**0.033**	0.781	**0.015**

Values in bold mean they are statistically significant

*Yates correction for the χ^2 test; p values adjusted for the clustering design effect

C-section cesarean section, *SMM* severe maternal morbidity

have not analyzed women's residency in this study, we have previously demonstrated that delays in obstetric care impact directly the maternal morbidity and mortality; especially regarding access to health services, difficulties with transportation to a hospital were 12-fold more frequent in MD cases when compared to PLTC ($p < 0.001$) [18]. Domingues et al. [25] have also pointed to this direction, when observed that seeking care in two or more institutions before admission for delivery quadruplicated the MNM incidence. Thus, it is understandable why any degree of obstacles in receiving adequate obstetric care impact directly the infant health, they introduce a domino effect, which can culminate in fetal/neonatal death, or even surpass the perinatal period, considering the poor prognosis of neonatal hypoxia and asphyxia. Our data highlight that easy access to adequate health care in complicated pregnancies is a real need [18, 26], and future analysis would clarify which sort of delay affected the most the perinatal health.

We have found that maternal and fetal/neonatal severity of compromise is directly proportional, with higher prevalence of adverse perinatal outcomes in cases of MNM and MD, which is in accordance with the literature [7, 8, 27, 28]. Therefore, worse obstetric outcomes contributed significantly to the increased neonatal mortality, along with lower gestational age at delivery and lower birthweight. Preterm birth remains as one of the main reasons for the high neonatal death rates, characterized by a very slow decline, yet [2, 3, 29]. Prematurity is strongly related to birthweight. Although the cutoff of 2500 g is widely used as a measure of quality of care and mortality risk, there are still questions about its role in the neonatal mortality pathway and its clinical interpretation [17]. Even considering that we [9, 27, 28] have found that a more advanced gestational age at delivery and a higher birthweight are less associated with adverse perinatal outcomes, we cannot rule out the participation of confounding factors, such as maternal nutritional or recreational habits, and environmental influences. Paraphrasing the obstetric transition concept [24], when secondary and tertiary prevention and avoidance of delays in care have growing importance in decreasing maternal mortality,

Table 4 Multivariable analysis of independently associated factors with adverse perinatal outcomes

Model/predictors	PR	95% CI	*P*
Model 1: fetal death ($n=6659$)			
Birthweight (kg)	0.28	0.22–0.78	< 0.001
No onset of labor	0.51	0.31–0.84	0.010
Cephalic presentation	0.60	0.46–0.78	< 0.002
Age (years)	1.03	1.01–1.06	0.006
Hypertension as cause	1.72	1.14–2.62	0.012
Any delay	1.96	1.49–2.59	< 0.001
Group (MNM, MD)	2.59	1.66–4.04	< 0.001
Vaginal delivery	2.88	1.87–4.44	< 0.001
Hemorrhage as cause	2.90	1.81–4.66	< 0.001
Model 2: 5th min Apgar score < 7 ($n=6375$)			
Birthweight (kg)	0.59	0.40–0.88	0.012
Cephalic presentation	0.60	0.44–0.80	< 0.002
No onset of labor	0.75	0.57–0.98	0.036
Gestational age at birth (weeks)	0.87	0.81–0.95	0.002
Clinical surgical cause	1.47	1.01–2.16	0.047
Any delay	1.61	1.32–1.96	< 0.001
Hemorrhage as cause	1.98	1.37–2.85	< 0.002
Group (MNM, MD)	2.39	1.68–3.39	< 0.001
Model 3: neonatal death ($n=6792$)			
Birthweight (kg)	0.31	0.18–0.54	< 0.001
Gestational age at birth (weeks)	0.81	0.74–0.89	< 0.001
Any delay	1.43	1.07–1.91	0.017
Hemorrhage as cause	1.48	1.13–1.95	0.006
Clinical/surgical cause	1.56	1.08–2.25	0.020
Model 4: any adverse perinatal outcome ($n=5674$)			
Birthweight (kg)	0.48	0.36–0.65	< 0.001
No onset of labor	0.58	0.46–0.74	< 0.001
Cephalic presentation	0.73	0.59–0.91	0.008
Gestational age at birth (weeks)	0.89	0.84–0.94	< 0.001
Marital status (with partner)	1.18	1.01–1.37	0.036
Hypertension as cause	1.53	1.06–2.21	0.024
Any delay	1.58	1.31–1.91	< 0.001
Group (MNM, MD)	1.85	1.46–2.35	< 0.001
Clinical surgical cause	1.93	1.22–3.06	0.007
Hemorrhage as cause	2.16	1.59–2.94	< 0.001

Analysis performed by Poisson regression, considering the cluster design (center)

PR prevalence ratio, *CI* confidence interval, *PLTC* potentially life-threatening condition, *MNM* maternal near miss, *MD* maternal death

Main outcomes: Model 1: fetal death (yes: 1/no: 0); Model 2: 5th min Apgar score < 7 (yes: 1/no: 0); Model 3: neonatal death (yes: 1/no: 0); Model 4: any adverse perinatal outcome (yes: 1/no: 0); Predictors: group: (MNM, MD: 1/PLTC: 0); age (years); ethnicity (white: 1/non-white: 0); schooling (up to primary: 0/high, superior: 1); marital status (with partner: 1/without: 0); parity (0/≥ 1: 1); number of prenatal visits (< 6: 0/≥ 6: 1); financial coverage for delivery (public: 1/other: 0); gestational age at delivery (weeks); onset of labor (no: 1/spontaneous, induced: 0); mode of delivery (vaginal: 1/cesarean section: 0);—any delay: (yes: 1/no: 0); fetal presentation (cephalic: 1/other: 0); birthweight (kg); hemorrhage as cause (yes: 1/no: 0); hypertension as cause (yes: 1/no: 0); infection as cause (yes: 1/no: 0); clinical surgical cause (yes: 1/no: 0)

the drop in perinatal deaths due to preventable causes will follow large-scale investments in infrastructure, education, and social development.

Not surprisingly, vaginal delivery was associated with fetal death. In fact, it is reasonable to suppose that cesarean sections were timely offered, as they were not associated with low Apgar scores or neonatal death. It is important to note that appropriate access to cesarean delivery is a life-saving procedure, for mothers and babies, and may even appear as a preventative factor for stillbirths [19]. On the other hand, it can be related to the maternal illness severity, since cesarean sections are more commonly performed in any pathological condition, even in less severe cases [28]; or it is more likely to be performed when there is a greater probability of delivering an alive fetus [19]. Therefore, in this study, cesarean delivery may have been proceeded either as cause or as result of complications, and it is difficult to evaluate its actual role in the process [30].

The remarkable relationship between haemorrhagic, hypertensive, and clinical/surgical conditions with adverse perinatal outcomes highlights, once more, that preventing direct maternal deaths means avoiding perinatal deaths. We have found maternal hemorrhage associated with all perinatal adverse outcomes, being twofold more prevalent in these cases; other's findings also relate antepartum or postpartum hemorrhage to fetal [7, 9, 19] or neonatal deaths [7, 31]. Although we did not differentiate the type of bleeding or time of infant death, our results indicate that they involve a continuum of care. We hypothesize that timely diagnosis (sometimes during the antenatal period) and treatment of maternal conditions (including performing cesarean sections and transfusion of blood products) will increase the likelihood of identifying high-risk fetuses and, virtually, eliminate preventable fetal and early neonatal deaths. Skilled care for women experiencing these situations is recommended [2, 7, 32–34], and team training (e.g., for using partograph), dissemination of protocols, and organization of alert systems are all institutional policies that could be implemented [35].

In this context, the WHO criteria for PLTC have proved to have good performance in identifying MNM and MD in Latin America. The positive likelihood ratio for maternal hemorrhage, for example, was 11.0 (95% CI 3.4–35.4), for placenta praevia, and reached 161.9 (95% CI 15.0–1748.7) for placenta accreta [27]. Besides that, a facility-based reviewing of MNM cases may decrease ratios of maternal mortality in about 23% (OR 0.77, 95% CI 0.61–0.98), and show a trend towards decreasing neonatal mortality as well (OR 0.92, 95% CI 0.65–1.3) [35]. It is expected that improvements in maternal care ultimately promote infant and childhood health [2], and represent the first step to virtually achieve all MDG. In near future, with the definition of the core outcomes in neonatology [36], and then harmonization of clinically important outcomes across populations,

we envision a greater advance in the perinatal care around the world.

Although comprehensive, this study has had some limitations. First, this was not a population-based study, and may not reflect entirely the quality of perinatal care in our continental country. However, centers from all five Brazilian regions were considered, and then we expect a reliable impression of obstetric and neonatal care. Second, all participating centers were referral tertiary facilities for perinatal care and have probably received the most complex cases in their regions. In reality, these complicated cases should exactly be followed in specialized institutions, by skilled professionals. Finally, assessment of medical charts only during women and children hospital stay did not permit a long-term evaluation of other consequences of those conditions. On the other hand, to the best of our knowledge, we have evaluated for the first time in Brazil the association between severe maternal morbidity and perinatal outcomes.

Conclusion

The current analysis confirmed that adverse perinatal outcomes are significantly more common among women with SMM. Poor formal schooling, lack of antenatal care, and difficult access of pregnant women to qualified and timely health care are the challenges to be overcome to decrease maternal and perinatal morbidity/mortality.

We demonstrated that there is a dose–response effect, i.e., the higher the severity of maternal morbidity, the more frequent are the adverse perinatal outcomes, particularly when associated with preterm birth and low birthweight. Maternal near miss and death were independently associated with the impaired perinatal outcomes, and hemorrhage has demonstrated the strongest association. Additionally, maternal and infant care should not be dissociated from social development: the close association between social and medical occurrences clearly shows the need to resolve these apparently widespread issues, to put the maternal and neonatal health in the agenda. In reality, these are simple issues that do not demand complex or high-cost structures, but major efforts into social, educational, and health-related development [21, 37–39]. We hypothesize that strategies designed for improving the obstetric health care are the cornerstone for reducing the neonatal death rates, and ultimately, infant mortality. We hope our results may clarify priorities to meliorate perinatal care.

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Author contributions DMZ has helped with project development and drafted the first manuscript. MAP has supervised the project development and edited the manuscript. SMH has designed the research proposal and managed the on-line data. MLC has supervised the project development and edited the manuscript. MHS has calculated the sample size and performed the statistical analysis. DFBL has collected data and edited the final version of the manuscript. JGC has designed the study proposal, supervised all the research procedures, and edited the final version of this manuscript.

Compliance with ethical standards

Conflict of interest This study was funded by CNPq/DECIT (The National Research Council and the Department of Science and Technology of the Brazilian Ministry of Health), Grant number 402702/2008-5. This manuscript is solely authors' responsibility and does not necessarily represent the official views of CNPq. CNPq did not influence on the decision to submit this manuscript or on its content. The authors declare that they have no conflict of interest.

Ethical statement All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee, and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent was waived. The research protocol was approved by the Institutional Review Board of University of Campinas on March 5th, 2009 (number 097/2009).

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