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Maternal near-miss at university hospitals with cesarean overuse: an incident case-control study

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Key words
Maternal near-miss, cesarean section, placenta previa, abnormally invasive placenta, Afghan migrant, health insurance, Iran

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Abstract

Introduction. Cesarean section carries a substantial risk of maternal near-miss morbidity. The aim of this study was to determine the frequency, causes, risk factors, and perinatal outcomes of maternal near-miss at three university hospitals with a high rate of cesarean section in Tehran, Iran. *Material and methods.* An incident case-control study was conducted from March 2012 to May 2014. The modified WHO near-miss criteria were used to identify cases. A control sample of 1024 women delivering at the study hospitals was recruited to represent the source population. Near-miss ratio, crude and adjusted odds ratios with confidence intervals were assessed. *Results.* Among 12 965 live births, 82 mothers developed near-miss morbidities and 12 died. The maternal near-miss ratio was 6.3/1000 live births. Severe postpartum hemorrhage (35%, 29/82), severe preeclampsia (32%, 26/82), and placenta previa/abnormally invasive placenta (10%, 8/82) were the most frequent causes of maternal near-miss. Women with antepartum cesarean section (adjusted odds ratio 7.4, 95% confidence interval 3.7–15.1) and co-morbidity (adjusted odds ratio 2.3, 95% confidence interval 1.4–3.8), uninsured Iranians (adjusted odds ratio 3.4, 95% confidence interval 1.7–7.1) and uninsured Afghans (adjusted odds ratio 4.7, 95% confidence interval 2.4–9.2) had increased risks of near-miss morbidity. Stillbirth and extremely preterm birth were the most prominent adverse perinatal outcomes associated with maternal near-miss. *Conclusion.* Overutilization of cesarean section clearly influenced the causes of maternal near-miss. A lack of health insurance had a measurable impact on near-miss morbidity. Tailored interventions for reducing unnecessary cesarean section and unrestricted insurance cover for emergency obstetric care can potentially improve maternal and perinatal outcomes.

Abbreviations: aOR, adjusted odds ratio; BMI, body mass index; CI, confidence interval; CS, cesarean section; MD, maternal deaths; MNM, maternal near-miss; NICU, neonatal intensive care unit; OR, odds ratio; WHO, World Health Organization.

Introduction

Good progress has been made in the improvement of maternal health, and dying in childbirth is now a rare event in many regions (1). However, the rise in cesarean

Key Message

Cesarean section overuse affects the causes of maternal near-miss in Tehran. Health insurance provides effective protection against near-miss morbidity.

section (CS) rates has become an increasingly challenging maternal health concern (2). A growing body of evidence indicates that there is a correlation between CS and maternal near-miss (MNM) for both index and subsequent pregnancies (2,3). MNM is defined as a woman who nearly died but survived life-threatening complications that occurred during pregnancy, childbirth, or within 6 weeks postpartum (4,5). A World Health Organization (WHO) working group has used this definition and developed a standard approach that has been introduced in different contexts to investigate MNM (5). The characteristics of MNM in settings where CS is infrequent may be unrepresentative for those contexts with a high rate of CS.

In recent years, Iran, a middle-income Asian country, has achieved a considerable decline in maternal mortality ratio (23/100 000 live births) and reproductive health indicators have improved (6). The total fertility rate is 1.9 births per woman, antenatal care coverage and skilled attendance at birth stands at 98%, and the proportion of institutional delivery is high (6). However, modern obstetrics has furthered the medicalization of childbirth and the national CS rates have increased substantially; from 38% in 2005 to 48% in 2009 (7).

The underlying reasons for this alarmingly high rate of CS are complex and inadequately identified (8). Changes in the maternal demographic profile, such as older age and prepregnancy comorbidity, are suggested to be important contributing factors; however, health system policies and financial and legal issues have indirectly affected obstetric practice (9). For instance, maternity care has become primarily the doctors' responsibility, even in low-risk births, and the number of employed obstetricians per live births at hospitals exceeds the number of midwives (8). The payment method is based on fees for services and obstetricians contend that the fee paid for vaginal birth is not worth the long-lasting stressful process (9). While doctors claim that CS is their defence mechanism against litigations, the percentage of appropriately performed CS is less than 50% in Tehran (9,10). Therefore, despite concerted efforts to reduce CS and promote vaginal birth, Tehran has one of the highest rates of CS in the world (74%), making the evaluation of MNM crucial in such a context (7,11).

The aim of the present study was to investigate the frequency, causes, risk factors, and perinatal outcomes of MNM at three university hospitals in Tehran with a high rate of CS.

Material and methods

An incident case-control study was carried out in three university hospitals affiliated with Shahid Beheshti University of Medical Sciences in Tehran between March 2012 and May 2014. Tehran province accommodates over 13.5 million inhabitants, with a large number of Afghan migrants (6,12). Primary health care, including antenatal visits, is provided free of charge for both citizens and migrants in public health centers (6). Secondary and tertiary care services are provided in approximately 140 public and private hospitals; of these, 42 are university sites (12). At public hospitals, patients have to pay either 10% of the care costs if they have insurance or the whole cost if they are uninsured. A majority of citizens (90%) are covered by at least one insurance scheme that is provided by one of the four main public health insurers (13,14).

The study sites consisted of one secondary and two tertiary university hospitals. The first site, with about 4500 deliveries annually, is located in a low-income zone and refers women with critical conditions to the tertiary hospitals. One of the two tertiary sites, with over 600 deliveries per year, is located in a high-income zone and has specialized consultative care, among others for hematologic and psychiatric diseases. The third site, in the middle-income zone, has over 1000 births annually and admits referrals with cardiac disease or neurosurgical complications. All three hospitals have intensive care units for adults and neonates (NICU), and labor wards are equipped with fetal heart rate monitors. Attending physicians and assistants in obstetrics and gynecology are on duty 24 h a day and have responsibility for all deliveries regardless of risks.

An MNM case was identified when a woman, while pregnant, during delivery, or within 6 weeks postpartum, experienced severe obstetric complications that resulted in developing a life-threatening event. The WHO near-miss criteria were modified to minimize false exclusions of those women whose lives were threatened due to obstetric complications but who would not fulfill the WHO criteria due to constraints in the provision of blood products and limited expertise at the secondary hospital (5). Table 1 shows the inclusion criteria for MNM cases. The modified indicators were transfusion of $\geq$4 units of blood and an acute decrease in the platelet count to $\leq$75 000 platelets/mL. A rapid reduction of $\geq$4 g/dL in hemoglobin concentration was also accepted as a near-miss event. One attending physician and one assistant in each hospital were members of our research group with whom several preparatory meetings were arranged in January 2012. During these meetings, the WHO near-miss approach was discussed and verbal and written instructions for completing the research forms were provided. The obstetric assistants identified MNM cases during daily morning reports and completed the research forms, all under the supervision of the attending physicians. The main

Table 1. Criteria used for identification of maternal near-miss at three university hospitals in Tehran, Iran, 2012–2014.

Potentially life-threatening conditions (severe obstetric complications)
Hemorrhagic disorders
Severe postpartum hemorrhage
Placenta previa (includes abnormally invasive placenta)
Placental abruption
Uterine rupture
Others (includes ectopic pregnancy, abortion, obstetric hemorrhage)
Hypertensive disorders
Severe preeclampsia, eclampsia
Severe systemic infection or sepsis
Thromboembolic disorders
Other disorders or comorbidities
Anesthetic complications, diabetes; chronic hypertension; cardiac, pulmonary, renal, hepatic, and hematologic diseases, severe anemia, previous pelvic operations, uterine scar
Life-threatening conditions (near-miss events)
Coagulation and hematological dysfunction
Transfusion of ≥4 units of blood,[a] acute thrombocytopenia ≤75 000/mL,[a] decreased hemoglobin ≥4 g/dL[b]
Cardiovascular dysfunction
Shock, cardiac arrest, pulmonary edema, cardiopulmonary resuscitation, use of continuous vasoactive medicine
Uterine dysfunction
Hysterectomy following hemorrhage or infection
Renal dysfunction
Oliguria non-responsive to fluids or diuretics, dialysis for acute renal failure, severe acute azotemia (creatinine ≥3.5 mg/dL)
Respiratory dysfunction
Acute cyanosis, gasping, respiratory rate >40 or <6 bpm, intubation and ventilation ≥60 min not related to anesthesia
Hepatic dysfunction
Jaundice in the presence of preeclampsia, bilirubin >6 mg/dL
Neurological dysfunction
Prolonged unconsciousness ≥12 h, stroke, uncontrollable fits
Metabolic dysfunction
Loss of consciousness, ketoacidosis
Others
Admission to intensive care unit, laparotomy/reoperation for hemorrhage or infection

Terminology adapted from reference (5).
[a]Modified criteria.
[b]Included criterion.

researcher performed the overall coordination of the data collection and periodically validated the collected data against the original records in hospital archives to minimize information bias.

For each case, the woman's level of education (illiteracy, primary and secondary school, university), family income (low if it barely paid household expenses, medium if it covered all such bills, and high if it exceeded household expenditures, as reported by the women), and body mass index (BMI) (≤18.5: underweight, 18.5–24.9: normal weight, ≥25: overweight and obese) were documented when cases were hospitalized.

A sample of women admitted to the maternity wards during the study period was selected to represent the source population on such wards, hereafter referred to as controls. A random starting point in the delivery room register list was chosen, and then every fifth woman was allocated systematically to accomplish the required sample for each of the hospitals. Demographic data for controls were used to estimate the distribution of maternal and medical background factors, and perinatal outcomes in the source population.

Background factors and perinatal outcomes (extremely preterm, preterm births, stillbirth, and admission to NICU) for both cases and controls were extracted from patients' notes. Maternal age (<20, 20–34, ≥35 years), parity (0, 1–2, ≥3 para), gestational age (extremely preterm <28, preterm 28–37, term 37–42, post-term >42 weeks), BMI, level of education, family income, addiction (use of any addictive drugs), insurance status, and nationality (Iranian and Afghan based on country of birth) were assessed as maternal factors. Gestational age was estimated based on the first day of the last menstruation period and sonographic evaluations or just the latter when menstrual dates were not recalled. Because almost all migrants and a number of Iranians had no health insurance, an independent variable was created and called "insurance-nationality" to classify nationality with different insurance status: insured Iranian, uninsured Iranian, insured Afghan, and uninsured Afghan.

Antenatal care coverage (a minimum of four visits), previous CS, mode of delivery (antepartum CS, intrapartum CS, and vaginal birth), severe anemia (hemoglobin <10 g/dL), comorbidity, and twin pregnancy were considered medical factors. Antepartum CS was defined as a CS performed before the onset of uterine contractions and cervical change, whereas intrapartum CS was performed when regular contractions had already started and resulted in cervical effacement. Comorbidity included diabetes, chronic hypertension, cardiac, pulmonary, renal, hepatic and hematologic diseases, as well as severe anemia, previous pelvic operations and uterine scar. Data on total deliveries (source population), live births, and stillbirths were collected from delivery room registers.

The Ethics Committee of Shahid Beheshti University of Medical Sciences approved the study protocol on 7 January 2012 (panel number: 129). As no direct contact with patients was involved, informed consent was not necessary.

Statistical analysis

A standardized mortality (or morbidity) ratio module by OPENEPI software, Version 3.03 (Open Source

Epidemiologic Statistics for Public Health, http://www.openepi.com), was used to estimate MNM ratios using all live births at the surveyed hospitals. We used a sample size calculator for descriptive studies by the aforementioned software to calculate the required sample size for controls. The number of deliveries in each hospital was considered as the population size, a CS rate of 60% was adopted as the anticipated frequency, and confidence limits of 5%, and a design effect of 1.0 were set, resulting in a total sample of 1024 controls. Statistical analyses were performed using SPSS software, Version 21 (IBM Corp., Armonk, NY, USA). The relation between maternal and medical background factors and MNM was computed by the Chi-squared test. Those factors that had a significant relation with MNM were used as independent variables for logistic regression models. Model 1 controlled for the interrelation of significant maternal and medical background factors. In Model 2, we added health insurance to background factors from Model 1 to adjust for the effect of this variable. In Model 3, "insurance-nationality" was substituted for "health insurance" and "nationality" in Model 2. The exploratory factors, such as maternal age, parity, and nationality, were controlled for collinearity. Differences were considered statistically significant if $p < 0.05$.

Results

During the 26-month period surveyed, there were 12 965 live births, 204 stillbirths, and 12 maternal deaths (MD)

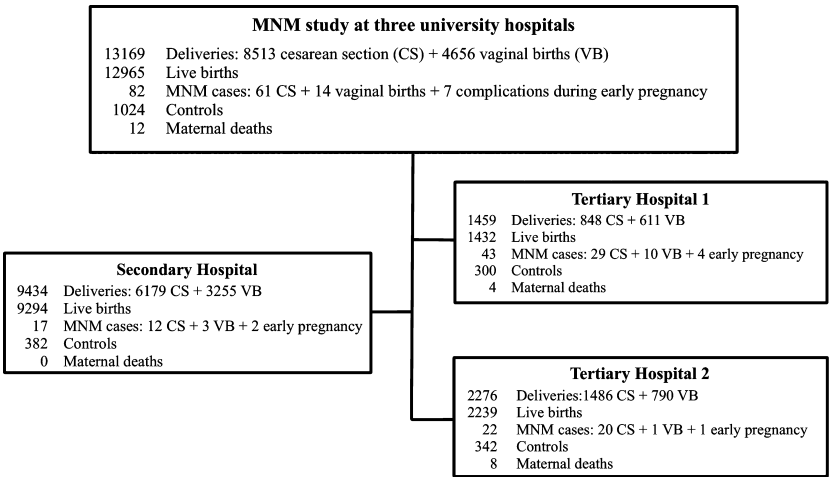

Figure 1. Flow diagram on source population, maternal near-miss (MNM) cases and controls at three university hospitals in Tehran, Iran, 2012–2014.

Table 2. Source population, control group, severe maternal outcome (SMO) and maternal near-miss (MNM) ratios at three university hospitals in Tehran, Iran, 2012–2014 (95% confidence intervals).

	Secondary Hospital	Tertiary Hospital 1	Tertiary Hospital 2	Total
Total deliveries	9434	1459	2276	13 169
Total live births	9294	1432	2239	12 965
Cesarean section rate	65.5%	58.1%	65.3%	64.6%
Controls	382	300	342	1024
MNM cases[a]	17	43	22	82
Maternal deaths[a]	0	4	8	12
MNM ratio[b]	2 (1.0–3.0)	30 (22.0–39.0)	10 (6.3–14.0)	6.3 (5.0–7.8)
SMO ratio[c]	2 (1.0–3.0)	33 (24.0–43.0)	13 (9.2–19.0)	7.2 (6.0–8.8)
Mortality index[d]	n/a	8.5%	27%	13%

[a]Includes referrals.
[b]MNM cases per 1000 live births.
[c]Sum of MNM cases and maternal deaths per 1000 live births.
[d]Maternal deaths divided by sum of MNM cases and maternal deaths.

at the three hospitals (Figure 1, Table 2). In addition, 82 MNM cases were identified; of these, 75 women gave birth: 81% (61/75) by CS and 19% (14/75) by vaginal birth, including four births at home. Five MDs (42%, 5/12) had been transferred to the tertiary hospitals from other hospitals, counties, and cities before they died. One-third (33%, 27/82) of all MNM cases were also referrals, 44% (12/27) of which were from the study site that provided secondary care. The severe maternal outcome ratio [(MNM + MD)/1000 live births] was 7.2, and MNM ratio (MNM/1000 live births) was 6.3, including referral cases, with a mortality index [MD/(MD + MNM)] of 13% (Table 2). The majority of cases (62%, 51/82) arrived at hospital in a critical condition or developed organ dysfunctions within 6 h of admission.

As Table 3 shows, MNM cases resulted mainly from severe postpartum hemorrhage (PPH) (35%, 29/82), severe preeclampsia/eclampsia (32%, 26/82), placenta previa and abnormally invasive placenta (AIP) (10%, 8/82). The most frequent near-miss events were due to coagulation-hematological (93%, 76/82), cardiovascular (22%, 18/82), and respiratory dysfunctions (21%, 17/82). Obstetric hysterectomy was the fourth most common near-miss event (17%, 14/82) and was mainly performed due to AIP (43%, 6/14). Admission to the intensive care unit was noted in 66% (54/82) of all MNM cases. Among MNM cases, 19% (16/82) and 2% (2/82) had two and three severe complications, respectively, and 40% (33/82) developed three or more near-miss events.

Table 3. Distribution of severe complications and organ dysfunctions among 82 maternal near misses at three university hospitals in Tehran, Iran, 2012–2014.

	n	%
Severe obstetric complications		
Severe postpartum hemorrhage	29	35
Severe preeclampsia and eclampsia	26	32
Placenta previa (includes abnormally invasive placenta)	8	10
Placental abruption	5	6
Ectopic pregnancy	5	6
Abortion	1	1
Obstetric hemorrhage	4	4
Purperal sepsis	6	7
Pulmonary embolism	2	2
Other[a]	16	21
Organ dysfunctions (near-miss events)		
Coagulation and hematologic	76	93
Transfusion of ≥4 units blood	41	50
Acute thrombocytopenia ≤75 000/mL	25	30
Decreased hemoglobin ≥4 g/dL	10	12
Cardiovascular	18	22
Respiratory	17	21
Uterine (obstetric hysterectomy)	14	17
Renal	7	8
Neurologic	4	5
Hepatic	1	1
Metabolic	1	1
Admission to intensive care unit	54	66
Laparotomy/reoperation	8	10

[a]Includes epilepsy, acute fatty liver, idiopathic or thrombotic thrombocytopenic purpurea, diabetic ketoacidosis, cardiomyopathy, and psychosis.

With regard to maternal factors, more than half of the MNM cases involved women who were illiterate or had only attended primary school. Sixty percent had low family incomes, and 40% were overweight or obese. However, no such data for the control group were available for analysis (Table 4). Crude odds ratios (OR) showed that, in comparison with controls, MNM cases were more likely in those aged ≥35 (OR 2.6, 95% CI 1.5–4.5), in multiparous women (parity ≥3) (OR 3.0, 95% CI 1.6–6.0), and in women of Afghan nationality (OR 2.1, 95% CI 1.2–3.5) (Table 4).

Among medical factors, comorbidity, severe anemia, previous CS, and antepartum CS in the index pregnancy were associated with MNM (Table 4). Conversely, the risk of MNM was less among those who had antenatal care (OR 0.4, 95% CI 0.2–0.8), who gave birth vaginally (OR 0.4, 95% CI 0.2–0.7) or who had health insurance (OR 0.4, 95% CI 0.2–0.6). A majority (90%, 754/834) of Iranians and only a few (3%, 4/132) Afghans were insured.

Repeat cesarean was the most common indication for CS (35%, 219/629) among controls, whereas this indication was 70% less likely (OR 0.3, 95% CI 0.1–0.6) in MNM cases. Instead, the leading cause of CS in MNM cases was severe preeclampsia (34%, 21/61). The odds of CS due to severe preeclampsia (OR 9.5, 95% CI 5.0–17.9), placenta previa/AIP (OR 11.0, 95% CI 2.7–45.1), and placental abruption (OR 3.6, 95% CI 1.1–11.6) were significantly higher in MNM cases than in controls (data are not shown in Tables).

The adjusted odds ratios (aORs) showed that MNM was associated with Afghan nationality (aOR 3.2, 95% CI 1.8–6.0), comorbidity (aOR 2.2, 95% CI 1.3–3.7), antepartum CS (aOR 6.4, 95% CI 3.2–12.9), and antenatal care coverage (aOR 0.4, 95% CI 0.1–0.9) (Model 1 in Table 5). Background factors were not highly correlated. By taking health insurance into account, the aforementioned associations with Afghan nationality and antenatal care coverage disappeared, but a protective association with health insurance (aOR 0.3, 95% CI 0.1–0.6) was found (Model 2). MNM was more likely among uninsured Iranians (aOR 3.4, 95% CI 1.7–7.1) and uninsured Afghans (aOR 4.7, 95% CI 2.4–9.2) than insured Iranians (Model 3).

Table 4. Comparison of maternal and medical background factors in maternal near-miss (MNM) cases and controls at three university hospitals in Tehran, Iran, 2012–2014.

Background factors	MNM cases		Controls		Odds ratio (95% CI)
	n = 82	%	*n* = 1024	%	
Maternal					
Age (years)					
<20	5	6	124	12	
20–34	58	71	771	77	2.6 (1.5–4.5)
≥35	19	23	105	11	
Missing			24	2.3	
Parity					
0	3	38	492	48	
1–2	38	46	467	46	
≥3	13	16	61	6	3.0 (1.6–6.0)
Missing			4	0.4	
Country of birth					
Iran	60	73	853	85	
Afghanistan	22	27	150	15	2.1 (1.2–3.5)
Missing			21	1.9	
Body mass index (kg/m^2)					
Underweight <18.5	6	7	–	–	n/a
Normal 18.5–24.9	43	53	–	–	
Overweight and obese ≥25	33	40	–	–	
Education					
Illiteracy	11	13	–	–	n/a
Primary school	34	42	–	–	
Secondary school	33	40	–	–	
University	4	5	–	–	
Family income					
Low	49	60	–	–	n/a
Medium	31	38	–	–	
High	2	2	–	–	
Addiction	3	4	14	1.4	2.7 (0.8–9.6)
Missing			18	1.8	
Health insurance	46	56	760	77	0.4 (0.2–0.6)
Missing			39	3.8	
Insurance-nationality					
Insured Iranian	46	77	754	90	
Uninsured Iranian	14	23	80	10	2.9 (1.5–5.4)
Insured Afghan	0	0	4	3	
Uninsured Afghan	22	100	132	97	
Missing			54	4.9	
Gestational age (weeks)					
Extremely preterm (<28)	9	12	12	1.8	11.2 (4.6–27.5)
Preterm (29–37)	27	36	155	15	3.0 (1.8–5.0)
Term (37–42)	39	52	821	80	0.2 (0.1–0.4)
Postterm (>42)	0	0	10	1	
Missing			26	2.5	
Medical					
Antenatal care coverage[a]	69	87	976	95	0.4 (0.2–0.8)
Missing			48	4.7	
Previous CS	27	33	227	22	1.7 (1.0–2.8)
Missing			20	1.9	
Mode of delivery					
Antepartum CS[b]	41	55	228	22	4.9 (2.6–9.2)
Intrapartum CS	20	26	401	39	1.4 (0.7–2.8)
Vaginal birth	14	19	389	38	0.4 (0.2–0.7)

Table 4. Continued

Background factors	MNM cases		Controls		Odds ratio (95% CI)
	n = 82	%	*n* = 1024	%	
Missing			6	0.5	
Severe anemia[c]	15	19	53	5	4.0 (2.0–8.0)
Missing			27	2.6	
Comorbidity[d]	41	50	276	27	2.7 (1.7–4.3)
Missing			4	0.4	
Twin pregnancy	5	6	34	3	1.9 (0.7–5.0)
Missing			28	2.7	

[a]Not applicable for three MNM cases with ectopic pregnancy (69/79).
[b]Cesarean section (CS) before the onset of uterine contractions and cervical change.
[c]Hemoglobin <10 g/dL.
[d]Includes diabetes; chronic hypertension; cardiac, pulmonary, renal, hepatic, and hematologic diseases; severe anemia; previous pelvic operations; uterine scar.

Table 5. Logistic regression analysis of maternal near-miss risk and preventive factors at three university hospitals in Tehran, Iran, 2012–2014.

Background factors	Model 1[a] aOR (95% CI)	Model 2[b] aOR (95% CI)	Model 3[c] aOR (95% CI)
Maternal			
Age (years)			
<20	0.8 (0.3–2.2)	0.8 (0.3–2.1)	
20–35	1.00		
≥35	1.9 (1.0–3.7)	1.8 (0.9–3.6)	1.8 (0.9–3.6)
Parity			
0	1.0 (0.5–1.7)	0.9 (0.5–1.7)	
1–2	1.00		
≥3	1.8 (0.8–4.1)	1.6 (0.7–3.6)	1.6 (0.7–3.7)
Nationality			
Iranian	1.00	1.00	
Afghan	3.2 (1.8–6.0)	1.3 (0.6–2.9)	
Health insurance	–	0.3 (0.1–0.6)	–
Insurance-nationality	–	–	
Insured Iranian			1.00
Uninsured Iranian			3.4 (1.7–7.1)
Uninsured Afghan			4.7 (2.4–9.2)
Medical			
Antenatal care coverage	0.4 (0.1–0.9)	0.4 (0.2–1.0)	0.4 (0.2–1.0)
Comorbidity	2.2 (1.3–3.7)	2.2 (1.3–3.7)	2.3 (1.4–3.8)
Mode of delivery			
Antepartum CS[d]	6.4 (3.2–12.9)	7.4 (3.7–15.0)	7.4 (3.7–15.1)
Intrapartum CS	1.7 (0.8–3.5)	1.8 (0.9–3.8)	1.8 (0.9–3.8)
Vaginal birth	1.00		

[a]Adjusted odds ratio (aOR) for maternal and medical factors.
[b]Adjusted odds ratio for Model 1 and health insurance.
[c]Adjusted odds ratio for Model 2 when insurance-nationality is substituted for health insurance and nationality.
[d]Cesarean section (CS) before the onset of uterine contractions and cervical change.

Maternal near-miss was clearly associated with preterm birth (OR 4.6, 95% CI 2.8–7.4), stillbirth (OR 12.0, 95% CI 5.0–31.5), and admission to NICU (OR 3.3, 95% CI 2.5–6.7). Neonatal death occurred in 7% (5/75) of MNM cases (Table 6).

Discussion

The MNM ratio at the hospitals studied was 6.3/1000 live births, with severe PPH, severe preeclampsia/eclampsia, and placenta previa/AIP as the major obstetric causes.

Table 6. Comparison of perinatal outcomes in maternal near-miss (MNM) cases and controls at three university hospitals in Tehran, Iran, 2012–2014.

Perinatal outcomes	MNM cases		Controls		Odds ratio (95% CI)
	n	%	*n*	%	
Extremely preterm birth (<28 weeks)	9	12	12	2	11.2 (4.6–27.5)
Preterm birth (28–37 weeks)	27	36	155	15	3.0 (1.8–5.0)
Preterm birth ≤ 37 weeks	36	48	167	17	4.6 (2.8–7.4)
Stillbirth	9	12	11	1	12.0 (5.0–31.5)
Neonatal intensive unit admission	23	31	118	12	3.3 (2.5–6.7)
Neonatal death	5	7	–	–	n/a

Comorbidity and antepartum CS correlated with MNM, whereas health insurance provided protection against near-miss morbidity.

The observed MNM ratio is in line with the ratio (6.1/1000 live births) cited by the WHO multi-country survey for countries with a moderate maternal mortality ratio, such as Iran (15). Nevertheless, the surveyed ratio is higher than the ratio of 5.1/1000 live births reported in a recent MNM study at public hospitals in Iraq (16). The difference between medical resources and co-existing morbidities among women admitted to public hospitals in Baghdad and tertiary university hospitals in Tehran could partly explain the higher ratio found in our study.

The majority of MNM cases resulted from severe PPH and severe preeclampsia/eclampsia, which is in accordance with earlier studies (15,16). However, to our knowledge, placenta previa/AIP has not been previously reported as the third-most common obstetric cause of MNM. AIP is a well-known consequence of CS in subsequent pregnancies and often leads to massive hemorrhage and obstetric hysterectomy (17,18). The frequency of the latter complication may be explained by the high rate of CS in the study hospitals (CS 63%; rate of prior CS 22%), compared with the WHO multi-country survey (CS 28.6%; rate of prior CS 12%) (15).

The most frequent near-miss events in our study were coagulation-hematological, cardiovascular, and respiratory dysfunctions, in agreement with other investigations (15,19). AIP was the leading cause of obstetric hysterectomy in our study, which is in accordance with publications from other countries with a high rate of CS (20). The high proportion of cases with admission to the intensive care unit can be explained by the availability of such critical care at all the study hospitals.

The correlation between CS and MNM we found after adjusting for possible confounders (age, parity, comorbidity) was in agreement with other studies from low- and high-income countries (3,21,22). However, the high prevalence of severe obstetric complications indicating CS among MNM cases may suggest that CS is a proxy for severe complications rather than a plausible cause for MNM. More detailed information that can be obtained from audits of CSs is required to attribute MNM solely to CS.

The correlation between MNM and lack of insurance was a new finding in our settings, although prior studies indicate that adverse maternal outcomes are more likely among immigrants and socially disadvantaged women in high-income countries (23–25). Dissociation from the health system affects women's care-seeking behavior and timely access to medical attention and may thus be associated with MNM (26,27). In Iran, financial resources for health care are inadequate; therefore, people incur high out-of-pocket payments (up to 55%) (14). The UN High Commissioner for Refugees reports that the provision of insurance coverage for hospital care for refugees is affected by international sanctions (28). The latter may partly explain the substantial unequal proportion of insurance coverage among Afghans compared with Iranians.

Our study is the first MNM study in a middle-income context with a high rate of CS and a huge influx of refugees. The findings should direct the attention of policy makers to the consequences of inappropriate obstetric practice and inadequate coverage for emergency obstetric care. The MNM ratio that we identified may be representative of other university hospitals in Tehran, as they serve women from similar socio-demographic groups and have comparable institutional resources. However, the same ratio is not transferable to other public or private hospitals in Iran because of socioeconomic differences in their clientele and the wide variation in the health care capabilities at those institutions. The small sample of MNM cases was a limitation in our study and could affect the related outcome measures. Patients' notes were the source of data collection for both MNM cases (prospectively) and controls (retrospectively). Improper documentation, especially for controls, could have affected our results with differential recording bias. The large hospital-matched control group and identical standard background factors for both cases and controls were used to reduce the bias. As one MNM case was identified while collecting data from the control sample and seven over-reported cases were excluded from the study, the surveyed MNM ratio might be slightly underreported. Practical limitations prevented us from following mothers after they were discharged from hospital. As a result, a few eligible MNM cases of women who may have developed complications at home and were subsequently admitted to other hospitals might have been lost.

The present study suggests that CS overuse affected the causes of MNM and led to obstetric hysterectomy. Uninsured mothers had significant risks of near-miss morbidity. As cesarean audit has been shown to be associated with the reduction of primary CS, implementation of such a strategy could serve to diminish unnecessary CS (11,29). Previous CS was the main indication for CS in our settings; therefore, it is necessary to attempt vaginal birth after CS in well-resourced hospitals (29). Above all, a health system reform to restore midwives' responsibility for low-risk births is crucial to achieve a sustainable reduction in CS rates. MNM was clearly associated with adverse perinatal outcomes; therefore, providing coverage of emergency obstetric care for all women, regardless of social and economic status, will avert adverse maternal and perinatal outcomes.

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