

CLINICAL ARTICLE

Obstetrics

Examining maternal morbidity across a spectrum of delivery locations: An analysis of the Global Network's Maternal and Neonatal Health Registry

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Abstract

Objective: To better understand maternal morbidity, using quality data from low- and middle-income countries (LMICs), including out-of-hospital deliveries. Additionally, to compare to the WHO estimate that maternal morbidity occurs in 15% of pregnancies, which is based largely on hospital-level data.

Methods: The Global Network for Women's and Children's Health Research Maternal Newborn Health Registry collected data on all pregnancies from seven sites in six LMICs between 2015 and 2020. Rates of maternal mortality and morbidity and the differences in morbidity across delivery location and birth attendant type were evaluated.

Results: Among the 280 584 deliveries included in the present analysis, the overall maternal mortality ratio was 138 per 100 000, while 11.7% of women experienced at least one morbidity. Rates of morbidity were generally higher for deliveries occurring within hospitals (19.8%) and by physicians (23.6%). The lowest rates of morbidity were noted among women delivering in non-hospital healthcare facilities (5.6%) or with non-physician clinicians (e.g. nurses, midwives [5.4%]).

Conclusion: The present study shows important differences in reported maternal morbidity across delivery sites, with a trend towards lower morbidity in non-hospital healthcare facilities and among non-physician clinicians.

KEYWORDS

low- and middle-income countries, maternal, morbidity, mortality, out-of-hospital deliveries, pregnancy

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1 | INTRODUCTION

The international community has long recognized the importance of reducing maternal morbidity and mortality, as set forth in the 2000 United Nations' Millennium Development Goals and continued in the 2015 Sustainable Development Goals. This focus has been associated with important declines, as the number of annual global maternal deaths has fallen from about 532 000 in 1990 to 303 000 in 2015.¹ As maternal mortality falls, a more nuanced approach is needed to understand the various forms of morbidity that affect the short- and long-term health of women.

There are few published data on the various forms of maternal morbidity. Though WHO estimates that 15% of pregnancies will be associated with some adverse outcome, more data are needed to improve our understanding of key morbidities.^{2,3} In order to standardize analysis of maternal morbidity, WHO developed the maternal near-miss criteria.⁴ Numerous studies have been published globally on maternal near-miss with rates in the range of 0.6%–15%. An analysis from the Global Network for Women's and Children's Health Research Maternal Newborn Health Registry (GN MNHR) found a rate of maternal near-miss of approximately 4% using modified WHO criteria.^{5,6} However, the WHO maternal near-miss criteria rely on data from hospital settings and are difficult to apply in low-resource settings, especially for out-of-hospital births.^{6–8} Given that an estimated 22% of births still occur outside of hospitals worldwide, it is essential to include data from these births when estimating maternal morbidity and mortality.² Additionally, near-miss events include only the most severe forms of maternal morbidity and fail to take into account other adverse pregnancy outcomes that, although not life-threatening, may significantly impact women and their families.⁷

The aim of the present study was to estimate the incidence of maternal morbidity within a population-based cohort that includes a large proportion of out-of-hospital deliveries. Individual and

composite rates of morbidity are examined across different delivery locations and types of providers to help understand the environment in which these outcomes are taking place. Finally, these rates are compared to published data from a variety of global contexts.

2 | MATERIALS AND METHODS

The present analysis was conducted using data from the GN MNHR between January 2015 and December 2020. The GN is a research partnership between U.S.-based academic institutions and institutions based in low- and middle-income countries (LMICs). In 2008, the Global Network initiated the MNHR, a prospective, population-based perinatal registry.⁹ The GN MNHR data for this study are from communities at seven sites across six low-income countries (Ubangi province, Democratic Republic of the Congo [DRC]; Chimaltenango, Guatemala; Nagpur site, Maharashtra State, India; Belagavi, Karnataka State, India; western Kenya; Thatta District, Pakistan; and Lusaka, Zambia). This analysis includes data collected after 2015, when important changes were made to the data collection methods within the GN to strengthen the classification of maternal cause of death. Data from the Bangladesh site are not included, as the site joined the registry in 2019.⁹

The methods and data quality monitoring of the GN MNHR have been published elsewhere.^{9,10} In general, each site identified eight or more geographically defined communities, each of which represents the catchment area of a primary healthcare center, with approximately 300–500 annual births each. The objective of the GN MNHR is to enroll pregnant women by 20 weeks of pregnancy and to obtain data on pregnancy interventions and outcomes for all deliveries that take place within the catchment area. Community health workers or nurses are recruited from the local community to identify and track pregnancy outcomes in coordination with community leaders, birth

attendants, and other healthcare workers. All pregnant women who provide consent are enrolled in the MNHR. Once a pregnant woman is identified, consented, and enrolled, staff obtain basic health information at enrollment. For this analysis, women who were lost to follow-up before delivery and pregnancies lost at less than 20 weeks of gestation were excluded (Figure 1). Data are formally collected at three time-points: at initial antenatal enrollment, within 72 hours of delivery, and at 42 days postpartum, though additional informal visits are conducted to foster connection with the family.

Definitions used by the GN MNHR for maternal morbidity and mortality are shown in Table 1. These definitions are consistent with those developed by WHO.¹¹ Maternal morbidities are self-reported or obtained from patient's own records by trained research staff at the specified time-points. Delivery facilities are classified as hospitals if they offer emergency obstetric or neonatal care services including provision of cesarean deliveries and safe blood transfusion. Facilities are defined as a clinic/health center if they are primarily an outpatient, non-hospital health facility without emergency obstetric or neonatal care. If deliveries occur outside of either of these facilities, including in transit to a facility, they are classified as home deliveries.

The GN MNHR has been approved by the institutional review board and ethics review board of all participating foreign and domestic institutions.¹⁰ The present study was reviewed and approved by the GN MNHR steering committee with representation from all study sites. All women provided informed consent for participation, including use of de-identified data in future analysis.

3 | RESULTS

Between January 2015 and December 2020, 301 122 pregnant women were enrolled in the MNHR at the seven sites, and 280 584 eligible pregnancy outcomes past 20 weeks were recorded (Figure 1). The number of delivery outcomes recorded at each site was in the range of approximately 36 000–53 000. Most women were aged 20–29 years, and only 5.7% were of advanced maternal age (>35 years). The amount of schooling varied widely by site, with women having no formal schooling ranging from 1.3% at the Kenya site to 82.6% at the Pakistan site. Attendance to antenatal care was relatively high, with 62.7% of women attending four or more antenatal care visits and only 1.8% of women with no prenatal care (Table 2). Across all sites, one-third of deliveries were attended by a physician, although this varied from 1.9% in the DRC to 74.3% in Nagpur, India. A nurse, midwife, or community health worker attended 44% of deliveries overall, while 17% of deliveries were attended by traditional birth attendants. One in five births (19.5%) occurred at home, 37.3% in a clinic or health center, and 43.2% in a hospital (Table 2).

As shown in Table 3, rates of hemorrhage were similar across sites, with an average rate of severe antepartum hemorrhage of 0.8% (range 0.2%–2.0%) and a mean severe postpartum hemorrhage (PPH) rate of 1.2% (range 0.2%–2.8%). Overall, hypertensive disease, including gestational hypertension, pre-eclampsia, and eclampsia, was reported to occur in 2.4% of all pregnancies (range 0.1%–4.4%) and perinatal/postpartum infections were reported to occur in 1.6% of pregnancies (range 0.3%–3.8%). Obstructed labor/

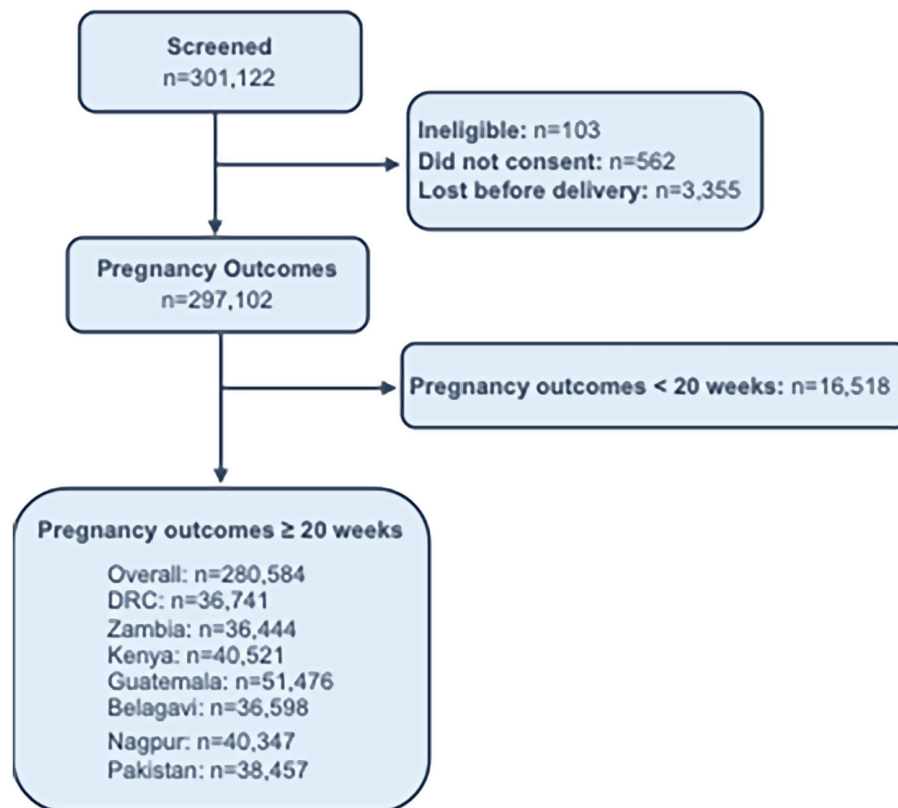


FIGURE 1 Consort diagram of women included for analysis

TABLE 1 GN MNHR standardized definitions of maternal morbidity and mortality

Maternal adverse outcome	GN MNHR definition
Severe antepartum hemorrhage	Self-reported blood loss >1000ml after the 22nd week of pregnancy and before the onset of labor
Severe postpartum hemorrhage	Self-reported blood loss of >1000ml within 24h after vaginal delivery, or >1500ml within 24h after cesarean delivery
Evidence of hypertensive disease, pre-eclampsia/ eclampsia, coma	Systolic blood pressure \geq 140mm Hg and a diastolic blood pressure \geq 90mm Hg on two or more occasions after 20weeks of pregnancy. If urine was assessed, substantial proteinuria was evidenced by +, ++, or +++
Severe infection or sepsis	A serious illness with symptoms that can include fever, chills, rapid breathing, rapid heart rate, rash, confusion, and disorientation. Hypotension and cold, clammy skin can also occur
Transverse, oblique, or breech lie	Orientation of the fetus perpendicular or at 45° to the long axis of the uterus, or orientation of the fetus where the buttocks, feet, or knees are presented first in the birth canal
Obstructed labor/failure to progress	Regular, rhythmic, painful contractions accompanied by cervical dilation that lasts >12h in multigravida or >24h in primigravida women
Maternal death	Death of a woman during pregnancy or within 42 days of the end of a pregnancy from any cause related to or aggravated by the pregnancy, but not from accidental causes or assault, trauma, or suicide

Abbreviation: GN MNHR, Global Network for Women's and Children's Health Research Maternal Newborn Health Registry.

failure to progress was noted in 5.8% of pregnancies overall (range 3.2%–9.7%). The rates of severe morbidities such as seizures/coma and obstetric fistula (data not shown) were too low to make meaningful comparisons and so are not included here. Reported rates of morbidity were higher in hospital deliveries for all morbidities except PPH and infection. When considering maternal morbidity by birth attendant, a similar trend of increased morbidity was seen with physician-attended deliveries (Table 4).

To understand larger trends in maternal risk, we determined the proportion of pregnancies that had at least one morbidity, and those that had two or more morbidities. Overall, 11.7% of pregnancies had at least one morbidity, and 1.7% of pregnancies had two or more. This overall morbidity measure was substantially higher for hospital deliveries, with 19.8% of pregnancies with at least one morbidity and 2.5% with two or more. The same trend was seen for physician-attended deliveries, with at least one morbidity noted in 23.6% of physician-attended deliveries and two or more morbidities noted in 2.8% of physician-attended deliveries (Table 4).

The overall maternal mortality ratio (MMR) was 138 per 100000 live births, which ranged widely across sites (Table 3). While Zambia and Kenya had MMRs close to 70 per 100000 live births, the MMRs in the DRC and Pakistan were more than three times that. The highest MMR was observed in women who delivered without a medical professional (Family/Self/Other; 186 per 100000) and was least in women delivering with a nurse, midwife, or other health worker (44 per 100000) (Table 4). Those delivering in clinics or health centers had one-third the MMR as those that delivered at home. However, as was observed with morbidity, the MMR among those delivering in hospitals or with physicians was substantially higher.

4 | DISCUSSION

The present analysis of a prospective population-based cohort of approximately 280000 pregnant women from six LMICs adds to the

growing body of evidence regarding population level rates of direct maternal morbidities and reveals important differences in outcomes based on location of and type of provider at delivery. Comparisons between studies, however, are hampered by differences in definitions of morbidities and in methods of measurement.

The rate of severe antepartum hemorrhage in the present study, 0.8%, was lower than that found by the Alliance for Maternal and Newborn Health Improvement (AMANHI) group, though it is similar to findings of a systematic review of obstetric hemorrhage by Zafar et al.,¹² which found an antepartum hemorrhage rate of 0.59% in LMICs. Findings from a population-based study in Malawi were also similar (1.3%).¹³ The rate of severe PPH observed in our study, 1.2%, is similar to other systematic reviews and population-based studies.^{3,12,14–18} However, objectively measuring the amount of blood loss is difficult, and methods of measurement vary greatly between studies.¹⁵ Subjective measurement, even by trained health workers, is imprecise, and typically underestimates the amount of blood lost in situations of high-volume loss.¹⁹

Our measurement of hypertensive disease of pregnancy includes chronic hypertension, gestational hypertension, pre-eclampsia, and eclampsia and, at 2.4%, is lower than most published estimates, which are in the range of 7%–16%.^{14,20} This difference may be due to several factors: heterogeneity in the reporting of blood pressure and proteinuria measurements across different sites and infrequent access to these measurements in out-of-hospital births. Despite WHO's endorsement of routine blood pressure and proteinuria screening as essential prenatal care,²¹ these assessments are not always performed in Global Network settings. In addition, information about hypertension/pre-eclampsia and eclampsia are self-reported and research staff may not have access to medical records, which limits differentiation between types of hypertension. Interestingly, reported rates of hypertensive disease are much higher for hospital deliveries, 4.7%, and for deliveries attended by physicians, 5.6%. While the underlying mechanism for this difference is unknown, it is likely

TABLE 2 Maternal and delivery characteristics by site^a

Characteristics	Overall	DRC	Zambia	Kenya	Guatemala	Belagavi	Nagpur	Pakistan
Mothers	280584	36741	36444	40521	51476	36598	40347	38457
Maternal age (years)	280533	36739	36441	40477	51476	36598	40346	38456
<20	41157 (14.7)	7639 (20.8)	8658 (23.8)	8864 (21.9)	8804 (17.1)	4479 (12.2)	1011 (2.5)	1702 (4.4)
20–35	223497 (79.7)	25793 (70.2)	24852 (68.2)	29769 (73.5)	37468 (72.8)	31984 (87.4)	39102 (96.9)	34529 (89.8)
>35	15879 (5.7)	3307 (9.0)	2931 (8.0)	1844 (4.6)	5204 (10.1)	135 (0.4)	233 (0.6)	2225 (5.8)
Maternal years of schooling	280522	36740	36443	40490	51476	36595	40323	38455
No formal schooling	59361 (21.2)	13479 (36.7)	2455 (6.7)	518 (1.3)	5900 (11.5)	4193 (11.5)	1053 (2.6)	31763 (82.6)
1–6 years	59689 (21.3)	15681 (42.7)	5943 (16.3)	5605 (13.8)	24011 (46.6)	3674 (10.0)	1758 (4.4)	3017 (7.8)
7–12 years	142517 (50.8)	7479 (20.4)	27468 (75.4)	30559 (75.5)	17525 (34.0)	25091 (68.6)	31205 (77.4)	3190 (8.3)
≥13 years	18955 (6.8)	101 (0.3)	577 (1.6)	3808 (9.4)	4040 (7.8)	3637 (9.9)	6307 (15.6)	485 (1.3)
Parity	279236	36740	36443	40498	51476	36597	40323	37159
0	88328 (31.6)	7023 (19.1)	11412 (31.3)	13492 (33.3)	15624 (30.4)	13347 (36.5)	20304 (50.4)	7126 (19.2)
1–2	115882 (41.5)	11140 (30.3)	14592 (40.0)	15911 (39.3)	21014 (40.8)	20696 (56.6)	19211 (47.6)	13318 (35.8)
>2	75026 (26.9)	18577 (50.6)	10439 (28.6)	11095 (27.4)	14838 (28.8)	2554 (7.0)	808 (2.0)	16715 (45.0)
Antenatal care visits	280325	36688	36444	40490	51410	36592	40282	38419
0	5134 (1.8)	1167 (3.2)	37 (0.1)	378 (0.9)	2290 (4.5)	12 (0.0)	23 (0.1)	1227 (3.2)
1–3	99545 (35.5)	18632 (50.8)	15932 (43.7)	14779 (36.5)	17333 (33.7)	8135 (22.2)	4204 (10.4)	20530 (53.4)
≥4	175646 (62.7)	16889 (46.0)	20475 (56.2)	25333 (62.6)	31787 (61.8)	28445 (77.7)	36055 (89.5)	16662 (43.4)
Delivery attendant	280440	36712	36433	40507	51469	36591	40331	38397
Physician	95305 (34.0)	681 (1.9)	1320 (3.6)	1425 (3.5)	31457 (61.1)	19430 (53.1)	29905 (74.1)	11087 (28.9)
Nurse/nurse midwife/LHW/HW	123826 (44.2)	27571 (75.1)	29864 (82.0)	31968 (78.9)	277 (0.5)	16443 (44.9)	10264 (25.4)	7439 (19.4)
Traditional birth attendant	47602 (17.0)	6681 (18.2)	1873 (5.1)	4411 (10.9)	19460 (37.8)	85 (0.2)	32 (0.1)	15060 (39.2)
Family/self/other	13707 (4.9)	1779 (4.8)	3376 (9.3)	2703 (6.7)	275 (0.5)	633 (1.7)	130 (0.3)	4811 (12.5)
Delivery location	280478	36713	36433	40507	51469	36591	40335	38430
Hospital	121058 (43.2)	3193 (8.7)	10084 (27.7)	9681 (23.9)	29501 (57.3)	21601 (59.0)	31581 (78.3)	15417 (40.1)
Clinic/health center	104681 (37.3)	26636 (72.6)	21014 (57.7)	22542 (55.6)	197 (0.4)	14116 (38.6)	8575 (21.3)	11601 (30.2)
Home/other	54739 (19.5)	6884 (18.8)	5335 (14.6)	8284 (20.5)	21771 (42.3)	874 (2.4)	179 (0.4)	11412 (29.7)
Delivery mode	280476	36711	36433	40507	51469	36591	40335	38430
Vaginal	234174 (83.5)	36136 (98.4)	35729 (98.1)	39392 (97.2)	35782 (69.5)	27641 (75.5)	26950 (66.8)	32544 (84.7)
Vaginal, assisted	739 (0.3)	83 (0.2)	48 (0.1)	49 (0.1)	12 (0.0)	261 (0.7)	95 (0.2)	191 (0.5)
Cesarean delivery	45563 (16.2)	492 (1.3)	656 (1.8)	1066 (2.6)	15675 (30.5)	8689 (23.7)	13290 (32.9)	5695 (14.8)

Abbreviations: DRC, Democratic Republic of Congo; HW, health worker; LHW, lay-health worker.

^aValues are given as number or number (percentage).

due in part to more frequent evaluation of blood pressure in healthcare settings. In addition, women experiencing a complication, such as eclamptic seizures, are more likely to be brought to a hospital for delivery.

Global estimates of obstructed labor are in the range of 8%–11%,^{14,17,22} higher than the finding of 5.8% in the present study. Again, large differences are noted in the rate of obstructed labor based on delivery location and provider. The rate of obstructed labor in hospital births is noted to be 10.7% compared to a rate of 1.9% in home births, and obstructed labor occurred in 13.0% of physician-attended deliveries compared to 2.1% of nurse-/midwife-attended

births. This is likely due to selection bias, as noted above, where women experiencing obstructed labor are more likely to be brought to a hospital and cared for by a physician.

Given that approximately one-quarter of deliveries globally still occur at home,² including these deliveries in estimates of maternal morbidity is key to understanding how to address them. The increased maternal morbidity and mortality for both hospital and physician-attended deliveries in the present study likely represents two phenomena. First, women who are known to have high-risk conditions before delivery are encouraged to deliver in hospitals and are also more likely to experience a variety of maternal morbidities.

TABLE 3 Maternal adverse outcomes by site^a

Adverse outcomes	Overall	DRC	Zambia	Kenya	Guatemala	Belagavi	Nagpur	Pakistan
Discrete adverse outcomes								
Obstetric hemorrhage	1.9 (1.8-1.9)	1.3 (1.2-1.5)	1.3 (1.2-1.5)	2.3 (2.2-2.5)	0.9 (0.9-1.0)	2.4 (2.2-2.6)	0.4 (0.4-0.5)	4.7 (4.5-4.9)
Severe antepartum hemorrhage	0.8 (0.7-0.8)	0.5 (0.4-0.6)	0.8 (0.7-0.9)	1.0 (0.9-1.1)	0.2 (0.2-0.3)	0.8 (0.7-0.9)	0.3 (0.2-0.3)	2.0 (1.9-2.2)
Severe postpartum hemorrhage	1.2 (1.1-1.2)	0.9 (0.8-1.0)	0.6 (0.5-0.6)	1.5 (1.3-1.6)	0.7 (0.7-0.8)	1.7 (1.5-1.8)	0.2 (0.2-0.2)	2.8 (2.6-3.0)
Hypertensive disease/eclampsia/ seizures	2.4 (2.3-2.4)	0.1 (0.1-0.1)	1.3 (1.2-1.4)	0.6 (0.5-0.7)	4.0 (3.9-4.2)	4.4 (4.1-4.6)	2.7 (2.6-2.9)	3.0 (2.8-3.1)
Pregnancy related infection: perinatal and postpartum	1.6 (1.6-1.7)	2.9 (2.8-3.1)	0.3 (0.3-0.4)	1.6 (1.4-1.7)	1.3 (1.2-1.4)	1.2 (1.1-1.3)	0.4 (0.4-0.5)	3.8 (3.6-3.9)
Obstructed labor/ failure to progress	5.8 (5.7-5.9)	3.2 (3.0-3.4)	3.2 (3.0-3.4)	4.2 (4.0-4.4)	5.2 (5.0-5.4)	9.7 (9.4-10.0)	7.9 (7.6-8.2)	7.2 (6.9-7.4)
Transverse/oblique/breech lie	1.9 (1.8-1.9)	0.9 (0.8-1.0)	0.9 (0.8-1.0)	0.9 (0.8-1.0)	3.3 (3.1-3.4)	1.7 (1.6-1.9)	1.7 (1.6-1.9)	3.3 (3.1-3.5)
Composite outcomes								
At least one adverse outcome	11.7 (11.6-11.8)	6.5 (6.2-6.7)	6.2 (5.9-6.4)	7.5 (7.2-7.7)	13.2 (12.9-13.5)	17.5 (17.1-17.8)	12.7 (12.4-13.0)	18.0 (17.6-18.4)
At least two adverse outcomes	1.7 (1.6-1.7)	1.8 (1.6-1.9)	0.9 (0.8-1.0)	1.8 (1.6-1.9)	1.5 (1.4-1.6)	1.8 (1.6-1.9)	0.5 (0.4-0.6)	3.5 (3.3-3.7)
Maternal Mortality Ratio ^b	138 (125-152)	245 (195-295)	72 (44-99)	65 (40-90)	96 (70-123)	103 (70-135)	100 (70-131)	313 (258-368)

Abbreviation: DRC, Democratic Republic of Congo.

^aValues are given as percentage (95% confidence interval).^bMaternal Mortality Ratio is maternal deaths per 100 000 live births. The 95% confidence interval for MMR is approximated using the variance of the proportion of maternal deaths.

Second, women who intend an out-of-hospital delivery may be brought to the hospital once a serious condition develops. This is demonstrated in the higher rates of obstructed labor seen in the hospital delivery group of the present study. There is a selection bias by which women who have developed or are in the process of developing an adverse outcome are brought to the hospital with little time left for prevention.

Interestingly, the morbidity rates are lowest in the group of women who deliver at non-hospital healthcare facilities. This same trend is seen in relation to delivering with a healthcare provider. While morbidity rates are highest among those delivering with physicians, this is likely based on the bias discussed above. Those delivering with nurses or midwives have lower reported rates of maternal morbidity. The underlying mechanisms for these trends are unknown and is an important area for further study. These findings support further investigation into the development of a system of levels of maternity care in LMICs, together with robust referral networks. Delays in recognition and transfer of women to higher levels of care are significant contributors to maternal morbidity, near-miss events, and even death, as has been demonstrated in prior studies.^{23,24} Yet, policies that encourage all women to deliver within hospitals may lead to a lower quality of care for all patients in settings where facilities do not have the capacity to care for the volume of deliveries in the community.²⁵

WHO has previously stated that 15% of women will experience some form of morbidity during pregnancy, though a systematic review by Gon et al.³ noted that the quality of available data on the majority of maternal morbidities were insufficient to make meaningful conclusions. Although our analysis included data from out-of-hospital deliveries, it is similarly limited by the quality of the data obtained. Overall, 11.7% of women were reported to have encountered at least one morbidity during pregnancy. Trends based on location of delivery and birth attendant remain similar; 19.8% of deliveries that occurred in a hospital had at least one morbidity, compared to 5.6% of deliveries in clinic/health centers. Of physician-attended deliveries, 23.6% had at least one reported morbidity, compared to 5.4% of nurse-/midwife-attended deliveries.

There are several strengths and limitations to this current analysis. The MNHR sites use common definitions, training, and protocols for data collection. Yet there are significant variations in outcomes by site that may represent differences in reporting of morbidities, and underreporting is especially important for home deliveries. Though some outcomes—such as blood transfusion, hysterectomy, and dilation and curettage procedures—are objective, more proximal outcomes such as PPH are self-reported or from the patient's own records and thus susceptible to bias. It is challenging to incorporate objective laboratory data in large population-based studies where these measures are not routinely used, as has been noted in other similar studies.^{5,14} There are several strengths as well. The present dataset includes outcomes from a large proportion of out-of-hospital births for which little data are currently published from LMICs. Additionally, this is a true population-level cohort, including nearly 99% of the pregnancies from the geographic areas included.

TABLE 4 Maternal adverse outcomes by delivery location and attendant^a

Adverse outcomes	Delivery location			Delivery attendant				
	Overall ^b	Hospital	Clinic/Health center	Home/Other	Physician	Nurse/Midwife/Health worker	Traditional birth attendant	Family/Self/Other
Discrete adverse outcomes								
Obstetric hemorrhage	1.9 (1.8-1.9)	2.0 (2.0-2.1)	1.8 (1.7-1.8)	1.7 (1.6-1.9)	2.1 (2.0-2.2)	1.6 (1.5-1.7)	1.7 (1.6-1.9)	3.3 (3.0-3.6)
Severe antepartum hemorrhage	0.8 (0.7-0.8)	1.1 (1.0-1.2)	0.5 (0.5-0.6)	0.6 (0.5-0.6)	1.1 (1.0-1.2)	0.5 (0.5-0.6)	0.5 (0.4-0.5)	1.6 (1.4-1.8)
Severe postpartum hemorrhage	1.2 (1.1-1.2)	1.0 (1.0-1.1)	1.3 (1.2-1.4)	1.2 (1.1-1.3)	1.0 (1.0-1.1)	1.1 (1.1-1.2)	1.3 (1.2-1.4)	1.8 (1.6-2.1)
Hypertensive disease/eclampsia/ seizures	2.4 (2.3-2.4)	4.7 (4.5-4.8)	0.6 (0.6-0.7)	0.6 (0.6-0.7)	5.6 (5.5-5.8)	0.7 (0.7-0.8)	0.6 (0.5-0.6)	1.0 (0.8-1.1)
Pregnancy related infection: perinatal and postpartum	1.6 (1.6-1.7)	1.7 (1.6-1.8)	1.6 (1.5-1.7)	1.5 (1.4-1.6)	1.8 (1.7-1.9)	1.5 (1.4-1.5)	1.4 (1.3-1.5)	2.4 (2.1-2.6)
Obstructed labor/failure to progress	5.8 (5.7-5.9)	10.7 (10.5-10.9)	2.1 (2.0-2.2)	1.9 (1.8-2.1)	13.0 (12.8-13.2)	2.1 (2.0-2.2)	1.5 (1.4-1.6)	3.6 (3.3-3.9)
Transverse/oblique/breech lie	1.9 (1.8-2.0)	3.4 (3.3-3.5)	0.7 (0.6-0.7)	0.9 (0.8-1.0)	4.3 (4.2-4.4)	0.6 (0.5-0.6)	0.8 (0.7-0.9)	1.1 (0.9-1.3)
Composite outcomes								
At least one adverse outcome	11.7 (11.6-11.8)	19.8 (19.6-20.0)	5.6 (5.5-5.7)	5.6 (5.4-5.8)	23.6 (23.4-23.9)	5.4 (5.3-5.5)	5.0 (4.8-5.2)	9.3 (8.8-9.8)
At least two adverse outcomes	1.7 (1.6-1.7)	2.5 (2.4-2.6)	1.0 (1.0-1.1)	1.0 (0.9-1.1)	2.8 (2.7-2.9)	1.0 (0.9-1.1)	0.9 (0.8-1.0)	1.9 (1.6-2.1)
Maternal Mortality Ratio ^c	100 (89-112)	135 (115-156)	46 (33-59)	128 (98-157)	153 (128-177)	44 (32-56)	120 (89-151)	186 (116-256)

^aValues are given as percentage (95% confidence interval).

^bExcludes 105 participants missing delivery attendant and location (1 missing attendant and 39 missing delivery location). This results in slight variation in overall rates from Table 3.

^cMaternal Mortality Ratio is maternal deaths per 100 000 live births. The 95% confidence interval for MMR is approximated using the variance of the proportion of maternal deaths.

In conclusion, estimates of maternal morbidity and mortality that exclude out-of-hospital deliveries may not estimate their true incidence. Our analysis shows important differences in maternal morbidity across delivery sites, with a trend towards lower morbidity in non-hospital healthcare facilities. Further investigation should be undertaken to better understand this trend as it could have implications on policies and funding for maternal health care.

AUTHOR CONTRIBUTIONS

AO and JW conceptualized the study and JM performed the data analysis. All authors participated jointly in the design of the study. SS, AL, AT, MB, LF, NFK, FE, EAL, SB, ABP, PLH, EC, WAC, SSG, RJD, MKT, EMM, and RLG oversaw study implementation and data monitoring. All authors approved the final manuscript.

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DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

CONFLICT OF INTEREST

The authors have no conflicts of interest.

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