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The Global Network Maternal Newborn Health Registry: a multi-national, community-based registry of pregnancy outcomes

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Abstract

Background: The Global Network for Women's and Children's Health Research (Global Network) supports and conducts clinical trials in resource-limited countries by pairing foreign and U.S. investigators, with the goal of evaluating low-cost, sustainable interventions to improve the health of women and children. Accurate reporting of births, stillbirths, neonatal deaths, maternal mortality, and measures of obstetric and neonatal care is critical to efforts to discover strategies for improving pregnancy outcomes in resource-limited settings. Because most of the sites in the Global Network have weak registration within their health care systems, the Global Network developed the Maternal Newborn Health Registry (MNHR), a prospective, population-based registry of pregnancies at the Global Network sites to provide precise data on health outcomes and measures of care.

Methods: Pregnant women are enrolled in the MNHR if they reside in or receive healthcare in designated groups of communities within sites in the Global Network. For each woman, demographic, health characteristics and major outcomes of pregnancy are recorded. Data are recorded at enrollment, the time of delivery and at 42 days postpartum.

Results: From 2010 through 2013 Global Network sites were located in Argentina, Guatemala, Belgaum and Nagpur, India, Pakistan, Kenya, and Zambia. During this period, 283,496 pregnant women were enrolled in the MNHR; this number represented 98.8% of all eligible women. Delivery data were collected for 98.8% of women and 42-day follow-up data for 98.4% of those enrolled. In this supplement, there are a series of manuscripts that use data gathered through the MNHR to report outcomes of these pregnancies.

Conclusions: Developing public policy and improving public health in countries with poor perinatal outcomes is, in part, dependent upon understanding the outcome of every pregnancy. Because the worst pregnancy outcomes typically occur in countries with limited health registration systems and vital records, alternative registration systems may prove to be highly valuable in providing data. The MNHR, an international, multicenter, population-based registry, assesses pregnancy outcomes over time in support of efforts to develop improved perinatal healthcare in resource-limited areas.

Study Registration: The Maternal Newborn Health Registry is registered at Clinicaltrials.gov (ID# NCT01073475).

Introduction

The Global Network for Women's and Children's Health Research (Global Network) supports and conducts clinical trials in resource-limited countries by pairing foreign and U.S. investigators, with the goal of evaluating low-cost, sustainable interventions to improve the health of women and children. Another goal of the Global Network is to build local research capacity and infrastructure. These activities are designed to strengthen local capacity for independent research that will ultimately contribute to improved health care systems. The Global Network was initiated in 2001 by the *Eunice Kennedy Shriver* National Institute of Child Health and Human

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Development (NICHD) with co-funding from the Bill & Melinda Gates Foundation.

Accurate reporting of births, stillbirths, neonatal deaths, maternal mortality, and measures of obstetric and neonatal care is critical to efforts to inform health policy and to improve pregnancy outcomes in resource-poor settings. Because most of the study sites in the Global Network are in geographic areas with weak health care systems, they lack precise data on maternal and newborn health outcomes and measures of care. The development of a registry of vital statistics was necessary to allow the Global Network to document maternal and neonatal outcomes, design trials to address the major causes of poor outcomes, and assess interventions to improve outcomes. Collectively, these results will inform public health policy.

The Global Network's Maternal Newborn Health Registry (MNHR) is a prospective, population-based registry of pregnancies at the Global Network sites. The MNHR began in May 2008, as an expansion of the population-based data collection tool established at sites for the FIRST BREATH Study, a clinical trial investigating the impact of newborn care training on perinatal mortality in resource limited areas in low and low-middle income countries [1,2]. The MNHR continued after the completion of this study. The primary purpose of the MNHR is to quantify and analyze trends in pregnancy outcomes over time in order to provide population-level statistics within defined geographic areas. In this way, the MNHR serves as a data collection tool for pregnancy outcomes in individual studies and provides data to plan future studies in the Global Network. Although the MNHR relies on a core set of data (see below), to support individual studies, investigators may propose time-limited supplemental data collection to the MNHR.

In this supplement, there are a series of manuscripts that use data gathered through the MNHR from 2010 through 2013. During this period, sites in the Global Network remained the same, and a consistent core set of variables was collected. The initial MNHR study sites were located in Argentina, Guatemala, Belgaum and Nagpur, India, Pakistan, Kenya, and Zambia. In 2013, following a competitive renewal at the end of an NICHD funding cycle, the site in Argentina was replaced by a site in the Democratic Republic of Congo. (See Table 1 for locations and principal investigators.) The purpose of this manuscript is to provide an overview of the MNHR; included is a brief description of the sites, its organization and management, and methods of data collection. Selected data describing the subjects enrolled in the MNHR from 2010 to 2013 are included to characterize the population and the perinatal health care. Outcomes during this period are examined in the accompanying manuscripts in this supplement.

Global Network MNHR Sites

The target population for the MNHR at each Global Network site is women who reside in or receive healthcare in a specified group of communities, also referred to as

Table 1. Sites of the Global Network for Women's and Children's Health Research

Location of Site	In-country Institution	US Institution	Senior Foreign Principal Investigator	US Principal Investigator
Corrientes, Argentina	Institute for Clinical Effectiveness and Health Policy, Buenos Aires	Tulane School of Public Health and Tropical Medicine, New Orleans, LA	Jose Bélizán	Pierre Buekens
Equateur Provence, Democratic Republic of Congo*	Kinshasa School of Public Health, Kinshasa	University of North Carolina-Chapel Hill	Antoinette Tshefu	Carl Bose
Kafue and Chongwe Provence, Zambia	University Teaching Hospital, Lusaka	University of Alabama at Birmingham	Elwyn Chomba	Waldemar Carlo
Chimaltenango, Guatemala	FANCAP, Fundación para la Alimentación y Nutrición de Centro América y Panamá Guatemala City	University of Colorado School of Medicine	Ana Garces	Nancy Krebs
Belgaum, Karnataka, India	Jawaharlal Nehru Medical College, Belgaum	Christiana Care Health Services, Newark, DE	Bhala Kodkany	Richard Derman
Thatta, Pakistan	Aga Khan University, Karachi	Columbia University	Omrana Pasha	Robert Goldenberg
Nagpur, India	Indira Gandhi Government Medical College, Nagpur	Massachusetts General Hospital for Children	Archana Patel	Patricia Hibberd
Western Kenya	Moi University, Eldoret, Kenya	Indiana University School of Medicine	Fabian Esamai	Edward Liechty
Data Coordinating Center	RTI International, Durham, NC		Elizabeth McClure	

*Participant in the MNHR since 2013 only.

clusters. Each cluster is defined by a geographic area where mothers receive primary perinatal care from designated healthcare facilities. Initially, for a cluster to be included in the MNHR, it was estimated to have 300 to 500 deliveries per year, although the number of annual deliveries has increased in many clusters over time. The clusters usually correspond to existing healthcare service delivery areas, such as an area or zone defined by the ministry of health in the participating country. The clusters are not intended to be representative of the demography or healthcare throughout the country; in general, they represent the resource-limited areas within countries. Each site has established between 10 and 20 research clusters and altogether, the MNHR enrolls approximately 70,000 pregnant women annually.

A brief description of each site follows. These include the Human Development Index (HDI) for each region in which the site is located. The HDI is a composite statistic of life expectancy, education, and income indices used to rank countries. Values are typically >0.850 in Western Europe and North America. In 2014, values worldwide ranged from 0.944 (Norway) to 0.337 (Niger) [3].

South Asian Sites (Figure 1)

India (Belgaum)
Location: The research site is within the northwestern corner of the southern state of Karnataka, India, with the site coordinating center located in Belgaum.

Setting: There are 18 clusters corresponding to the service areas of 18 primary health centers. Each is managed by a physician medical officer who works with nursing staff and auxiliary nurse midwives in associated sub-centers, the most peripheral outpost of the health care services. There are three tertiary care hospitals and eight secondary care hospitals serving the region as referral hospitals staffed by obstetricians, pediatricians and nurses. In addition to these public sector health facilities, there are several private sector maternity facilities within the site catchment area.

HDI: 0.508 [6].

Figure 1 South Asian Global Network Sites

India (Nagpur)
Location: The research site is within the state of Maharashtra, India, with the coordinating center in Nagpur.

Setting: There are 20 clusters corresponding to the service area of 20 primary health centers, each served by physician medical officers and nurses. These areas include 119 sub-centers where basic maternal and child care are provided. Referral care is provided in ten tertiary hospitals (two public sector and eight private sector), and 129 secondary hospitals (27 public sector hospitals and 102 private nursing homes).

HDI: 0.549 [6].

Pakistan
Location: Research sites are in two of five sub-districts within the Thatta district in the southern Sindh province, near the city of Karachi, where the site coordinating center is located.

Setting: The 20 clusters are served by over 75 health facilities, both public sector and private fee-for-service, providing maternal and child health services. This includes 47 primary health clinics, 25 secondary care facilities and 3 referral hospitals. Care in health clinics is typically provided by either paramedical staff, including nurses and lady health visitors or non-specialist physicians. Obstetricians provide care in referral hospitals.

HDI: 0.595 [8].

Sub-Saharan Africa Sites (Figure 2)

Kenya
Location: The research site is within the western region of Kenya in the counties of Busia, Bungoma and Kakamega, with the site coordinating center located in Eldoret.

Setting: There are 16 clusters served by 23 health facilities, most operated by the government and staffed by nurse-midwives and clinical officers and a single medical officer. Three hospitals in the area function as referral hospitals. Most physicians are generalists, with a small number of trained obstetricians and pediatricians.

HDI: 0.570 [7].

Zambia
Location: The research site is within the districts of Kafue and Chongwe located south and east of the capital city of Lusaka, Zambia, where the site coordinating center is located.

Figure 2 Sub-Saharan Africa Global Network Sites

Setting: There are ten clusters, eight of which have health posts. Care is provided primarily by nurse midwives in the health posts and by traditional birth attendants for home births. There are three district hospitals and a referral hospital in Lusaka. Specialty physicians are available in the referral hospital only.

HDI: 0.465 [9].

Democratic Republic of Congo
Location: The research sites are in the northern province of Equateur, with the site coordinating center in Kinshasa.

Setting: There are 14 clusters, each served by a health center. Care in health centers is provided by nurses. There are three hospitals staffed by physicians, nurse midwives and nurses; no specialty physicians are available.

HDI: 0.338 (note: this is the HDI for the entire country; regional estimates were not available) [3].

Latin American Sites (Figure 3)

Argentina
Location: The research site is within the provinces of Corrientes and Santiago del Estero are located in the northern region of Argentina, with the coordinating center in Buenos Aires.

Setting: There are six clusters, three in each province. Each cluster corresponds to a department (municipality) in which the vast majority of the births occur at a publicly-funded secondary level hospital. Care is provided primarily by physicians and midwives. There are two Provincial referral hospitals, each located in the provincial capital cities.

HDI: 0.828 [4].

Guatemala
Location: The research site is within the Chimaltenango region is located in the Western Highlands of Guatemala, with the coordinating center in Guatemala City.

Figure 3 Latin American Global Network Sites

Setting: There are 17 clusters served by one referral hospital, 30 health centers, and 42 health posts. Maternal and infant care in the hospital is provided mainly by obstetricians and general physicians, in health centers by physicians and nurses, and in health posts by auxiliary nurses. *HDI:* 0.679 [5].

MNHR Organization and Management

A MNHR Study Committee, constituted of investigators from each site and a representative from the NICHD and the Data Coordination Center (DCC; RTI, International), guides the general conduct of the MNHR (Appendix). The Committee oversees the use of MNHR data, data analyses and publications. Within each site, the MNHR is overseen by the senior foreign investigator and a country coordinator. In addition a field supervisor generally oversees the management of daily field activities for the MNHR. Each cluster employs a research administrator (RA) who is responsible for data collection and transfer to the DCC. Typically, the RAs are healthcare providers within the community. The RAs work closely with the existing healthcare service providers to help ensure that data describing pregnancies are comprehensive and accurate, as described elsewhere [10,11]. This work is facilitated by influential community leaders (e.g. village elders, birth attendants, and facility registries) [12]. In addition to field staff, each site employs a data manager who oversees data entry and data quality, including the process of resolving data edits.

Methods

Eligibility

Pregnant women are eligible for inclusion in the MNHR if they 1) reside or receive healthcare in the community (regardless of their site of delivery) or 2) deliver within the study cluster. Sites are encouraged to enroll women by 20 weeks of gestation; however, they can be enrolled at any time up to and including enrollment at the time of delivery. The overall goal is to capture the pregnancy outcomes of all eligible women. Each site uses site-specific strategies to achieve this goal. Birth attendants are sensitized to the study activities and are asked to report all deliveries in their communities, regardless of whether the delivery occurs at home or in a facility.

Enrollment

Study staff maintain detailed maps of all health facilities and the location of birth attendants within each cluster (Figure 2). Staff routinely contact birth attendants active within clusters to document home deliveries, and review hospital and clinic logs for facility births on a monthly basis. The study team monitors cluster-level monthly data to identify trends over time (e.g. a declining or erratic birth rate) that might suggest failed enrollment of all

women. At several sites, cell phone reporting by local village elders and traditional birth attendants has been effective [12]. Several sites have used annual household surveys to identify married women of reproductive age and to identify those likely to become pregnant in the ensuing year [10]. Where available, birth rates generated from the MNHR are compared to rates from local data sources such as ministry vital records to ensure accuracy in reporting.

Data collection

The MNHR describes populations by collecting data describing demographic and health care characteristics and major outcomes of pregnancy. *A priori* definitions are used to classify certain outcomes and characteristics. For example, a stillbirth is defined using a modification of the World Health Organization (WHO) criteria: birth of a fetus weighing >500 g (or >22 weeks gestation) in which no signs of life (breathing, crying, heartbeat, or movement) were evident [13]. Fresh stillbirths have these signs but no signs of maceration. Gestational age is estimated using last menstrual period (LMP), or clinical data such as physical examination, ultrasound and other available information when LMP is unknown. The intent is to record measured birth weight taken within 48 hours of delivery using scales provided by the study. When birth weight is not obtained, weight is estimated with the goal of distinguishing infants weighing less than and greater than 1000g and 2500g. Models and pictures are used to teach these concepts to community birth attendants. Birth attendant is categorized as physician, nurse or equivalent, traditional birth attendant (TBA), family or unattended, and site of delivery is categorized as hospital, health center or home (including the TBA's home or in-transit). Finally, antenatal care is defined as having at least one visit with a skilled health provider.

All definitions used by the MNHR are consistent with the WHO definitions, whenever possible. The primary reference guide for definitions is the *Integrated Management of Pregnancy and Childbirth: Pregnancy, Childbirth, Postpartum and Newborn Care: A guide for essential practice* [14].

Cause of deaths is assigned by the supervisory physicians based on their examination of all data available. Prior to 2014, there was no systematic method for assigning cause. This resulted in variability and inconsistency among sites in assignment of cause. For this reason, in 2014, a new system of assigning cause based on the collection of a defined data set and a computer algorithm was initiated [15].

Data are recorded at discrete time points, including demographic data at enrollment in the MNHR (which usually corresponds to the first antenatal care visit), and health care and outcomes at the time of delivery and at

42 days postpartum. Supplementary data are collected when a fetus, an infant or a mother dies at any time prior to 42 days postpartum.

Study staff collect all data on paper forms at each cluster; a supervisor performs a review of these forms for completeness and errors. Clerks enter these data into a computerized data management system, which contains basic logic checks. From each site, data are then transmitted to the DCC for central analyses, data edits, including inter- and intra-form consistency checks, and additional edits to ensure quality [16]. Data monitoring reports are reviewed monthly by each site team for completeness and consistency of data, as described elsewhere [11].

Annually, and in response to special inquiries, major outcomes of pregnancy and other perinatal health indicators are reported by the DCC. These include the following:

- Rates of pre-eclampsia/eclampsia, obstructed labor, hemorrhage, infection
- Site of delivery
- Birth attendant type
- Cesarean section rate
- Neonatal resuscitation rate
- Preterm birth rate
- Proportion of low birth weight newborns
- Maternal mortality rate
- Stillbirth rate
- Early neonatal mortality rate
- 28-day neonatal mortality rate
- Cause of maternal deaths within 42 days after delivery
- Cause of neonatal deaths within 28 days after delivery

Training

The RAs receive training on the completion of data forms, schedule of data collection and process for editing data forms. Birth attendants are trained to collect data and assess basic clinical variables and outcomes, including differentiation of stillbirths from early neonatal deaths, birth weight and assessment of gestational age. Birth attendants are also taught to distinguish macerated from fresh stillbirths using pictures depicting forms of maceration.

RA's have monthly meetings to review their data collection and refresher training on study definitions on an annual basis, with specific training held more frequently as needed.

Quality assurance

Each site develops a monitoring plan to ensure the quality of the data. The monitoring plan has several components, including a timetable for responding to edits and an assessment of responsibility for completeness of data collection, data quality, data accuracy and data entry [11].

To assist with monitoring activities, the DCC prepares monthly monitoring reports of unexplained inconsistencies. They also prepare specially designed, site-specific programs to assist each site in monitoring. Finally, periodic site visits are conducted at each site by representatives of the NICHD, the DCC and the US investigator to review the completeness and quality of data collection.

Ethical approval

The appropriate institutional review boards or ethics research committees of the participating institutions and the ministries of health of the respective countries approve the activities of the MNHR. Initially, approval was sought from the appropriate leader of the participating community. Informed consent for study participation is requested from each pregnant woman (and her partner when available). Study staff read an information page that has been translated into the local language to each women to inform her of the study purpose. There are no monetary reimbursements to participants, and there is no remuneration to the communities participating in the study. The Global Network Data Monitoring Committee, appointed by the NICHD, oversees and reviews activities of the MNHR at annual meetings.

MNHR Population Characteristics 2010-2013

Since the inception of the MNHR in 2008, more than 450,000 pregnant women have been enrolled. During the calendar years 2010-2013, 283,496 pregnant women were enrolled in the MNHR, representing 98.8% of those eligible (Table 2). Rates of enrollment by site varied from 95.0% in Argentina to 99.9% in the two Indian sites (data not shown). Of the pregnancies registered, we were able to obtain delivery data for 98.8% of women and 42-day follow-up data for 98.4% of those enrolled. No site had >5% loss to follow-up. The time of registration varied by site. For example 96% of women were registered within 4 weeks of delivery in Argentina. By contrast, in four sites, Belgaum, Nagpur, Pakistan and Zambia, over half of women were enrolled prior to the third trimester. Recently, efforts have been made to enroll women earlier in pregnancy so that early outcomes (e.g. miscarriage) can be counted with accuracy.

Table 2 lists characteristics of women enrolled in the MNHR at each site from 2010 to 2013. These data highlight differences in demography among sites. For example, women tended to be older in the South Asian sites compared to other sites, and were more likely to be primiparous at the Indian sites. Over 80% of women at the Pakistani site had no formal education. Table 3 lists selected features of perinatal care of the MNHR cohort.

Table 2. Demographic Features of Women Enrolled in the Maternal Newborn Health Registry 2010-2013

	Argentina	Guatemala	Zambia	Kenya	Pakistan	Nagpur	Belgaum	Total
Pregnant women, N	9,944	30,806	28,176	36,509	51,794	41,678	84,589	283,496
Maternal age, N (%)								
< 20	2,684 (27.1)	5,067 (16.5)	7,116 (25.3)	7,869 (21.9)	2,018 (3.9)	833 (2.0)	8,134 (9.6)	33,721 (11.9)
20-35	6,447 (65.2)	22,467 (73.0)	18,757 (66.8)	26,545 (73.9)	46,682 (90.5)	40,693 (97.7)	76,214 (90.2)	237,805 (84.2)
> 35	760 (7.7)	3,252 (10.6)	2,221 (7.9)	1,524 (4.2)	2,905 (5.6)	120 (0.3)	163 (0.2)	10,945 (3.9)
Education, N (%)								
No formal education	254 (2.6)	5,983 (19.4)	2,922 (10.5)	1,110 (3.1)	42,879 (83.1)	1,269 (3.0)	17,224 (20.5)	71,641 (25.4)
Primary	6,146 (62.7)	19,436 (63.1)	15,412 (55.1)	25,637 (71.3)	3,908 (7.6)	7,233 (17.4)	27,884 (33.2)	105,656 (37.5)
Secondary	3,258 (33.2)	5,037 (16.4)	9,123 (32.6)	7,897 (22.0)	3,028 (5.9)	24,761 (59.5)	31,101 (37.0)	84,205 (29.9)
University+	152 (1.5)	333 (1.1)	500 (1.8)	1,303 (3.6)	1,767 (3.4)	8,363 (20.1)	7,745 (9.2)	20,163 (7.2)
Parity, N (%)								
0	3,232 (32.8)	8,618 (28.0)	7,609 (27.1)	9,046 (25.2)	10,749 (20.8)	19,941 (47.9)	35,742 (42.5)	94,937 (33.7)
1-2	3,831 (38.9)	11,010 (35.7)	10,554 (37.5)	13,881 (38.6)	16,563 (32.1)	20,623 (49.5)	42,672 (50.8)	119,134 (42.2)
> 2	2,794 (28.3)	11,171 (36.3)	9,944 (35.4)	13,020 (36.2)	24,341 (47.1)	1,103 (2.6)	5,657 (6.7)	68,030 (24.1)
Mean (std)	1.9 (2.2)	2.4 (2.6)	2.1 (2.0)	2.2 (2.1)	3.0 (2.8)	0.7 (0.8)	0.9 (1.0)	1.7 (2.1)

Table 3. Characteristics of Deliveries of Women in the Maternal Newborn Health Registry 2010-2013

	Argentina	Guatemala	Zambia	Kenya	Pakistan	Nagpur	Belgaum	Total
Deliveries, N	9,902	30,262	27,877	35,667	50,275	41,424	84,581	279,988
At least one ANC visit, N (%)								
Yes	9,312 (95.0)	29,696 (98.2)	27,547 (98.9)	34,643 (97.2)	41,792 (83.5)	41,361 (99.9)	84,145 (99.7)	268,496 (96.1)
No	494 (5.0)	533 (1.8)	307 (1.1)	1,003 (2.8)	8,243 (16.5)	30 (0.1)	218 (0.3)	10,828 (3.9)
Delivery mode, N (%)								
Cesarean	3,469 (35.0)	5,580 (18.4)	305 (1.1)	550 (1.5)	4,489 (9.4)	7,701 (19.6)	11,211 (14.0)	33,305 (12.3)
Vaginal/Vaginal assisted	6,430 (65.0)	24,673 (81.6)	27,455 (98.9)	35,112 (98.5)	43,420 (90.6)	31,506 (80.4)	68,583 (86.0)	237,179 (87.7)
Birth attendant, N (%)								
Physician	7,163 (72.4)	12,951 (42.8)	692 (2.5)	717 (2.0)	12,687 (25.3)	24,383 (58.9)	48,871 (57.8)	107,464 (38.4)
Nurse/Midwife/HW	2,678 (27.1)	543 (1.8)	15,433 (55.4)	14,505 (40.7)	13,080 (26.1)	14,223 (34.4)	28,307 (33.5)	88,769 (31.7)
TBA	2 (0.0)	16,675 (55.1)	7,093 (25.4)	16,038 (45.0)	21,961 (43.7)	1,178 (2.8)	2,002 (2.4)	64,949 (23.2)
Family/Other	51 (0.5)	92 (0.3)	4,656 (16.7)	4,407 (12.4)	2,475 (4.9)	1,616 (3.9)	5,377 (6.4)	18,674 (6.7)
Delivery location, N (%)								
Hospital	9,789 (98.9)	12,048 (39.8)	3,453 (12.4)	4,616 (12.9)	14,186 (28.3)	27,433 (66.3)	55,761 (66.0)	127,286 (45.5)
Clinic	15 (0.2)	1,367 (4.5)	13,482 (48.4)	10,245 (28.7)	12,296 (24.5)	10,933 (26.4)	20,777 (24.6)	69,115 (24.7)
Home/Other	93 (0.9)	16,846 (55.7)	10,939 (39.2)	20,805 (58.3)	23,730 (47.3)	3,031 (7.3)	7,976 (9.4)	83,420 (29.8)
Gender, N (%)								
Male	5,153 (51.8)	15,494 (50.9)	14,703 (52.8)	18,300 (50.7)	25,564 (52.7)	20,555 (52.3)	41,663 (52.0)	141,432 (51.9)
Female	4,797 (48.2)	14,948 (49.1)	13,142 (47.2)	17,796 (49.3)	22,975 (47.3)	18,763 (47.7)	38,506 (48.0)	130,927 (48.1)
Birth weight (measured)								
< 2500g	646 (6.5)	3,927 (13.0)	1,494 (5.4)	1,061 (3.0)	6,657 (14.7)	6,300 (16.1)	11,557 (14.5)	31,642 (11.9)
≥ 2500g	9,302 (93.5)	26,361 (87.0)	25,987 (94.6)	34,257 (97.0)	38,507 (85.3)	32,800 (83.9)	67,892 (85.5)	235,106 (88.1)
Mean (std)	3286.1 (578.2)	2983.2 (469.1)	3119.0 (473.4)	3231.5 (486.7)	2915.1 (551.6)	2662.2 (418.8)	2746.4 (439.9)	2912.3 (517.5)

TBA=traditional birth attendant

The most striking differences among sites were the percent of women delivered by cesarean section, attendance at delivery by a physician and delivery in a facility. The associations of demographic and perinatal care characteristics with pregnancy outcomes are explored in other manuscripts in this supplement [10,11,18-29].

Strengths and Limitations

The Global Network MNHR provides prospectively collected, population-based pregnancy outcome for defined geographic regions within low- and middle-income countries. One of its strengths is the representative nature of the MNHR, which reduces bias of facility-based registries. Additionally, because it is a prospective study, it reduces some of the recall bias associated with periodic surveys [30,31]. Additionally, the MNHR uses standardized definitions and methods across disparate sites which allows for comparison. Finally, the large enrollment (approximately 70,000 annual pregnancies) allows for precision in documentation of relatively rare events, such as maternal mortality.

One of the limitations of the MNHR is the difficulty in ensuring the inclusion of all pregnancies, and especially those with early pregnancy loss. We acknowledge that pregnancies resulting in miscarriages and terminations are currently under-reported. Historically, at most sites, enrollment in the MNHR has been at the time of the first prenatal visit, and this was often after the first trimester. Some sites are now using strategies to encourage earlier initiation of prenatal care. It is hoped that this will result in earlier registration. There is also the potential for non-enrollment of pregnancies that are managed outside of the health care system. Despite this potential loss, we believe that our enrolled populations approach 100% of all women whose pregnancies reach the second trimester, based on reviews at each site with other existing data. For example, in a recent report from the Belgaum site, birth rates reported by the MNHR were higher than projected based on ministry data and other sources, indicating that the surveillance for the MNHR was more comprehensive than the available census data [10]. Some sites encounter challenges in tracking the outcomes of pregnant women who migrate in or out of the study clusters, for example women who travel to the homes of their mothers at the time of delivery. To address these challenges, numerous systems have been developed and, through monitoring, a relatively stable enrollment rate has been achieved at the affected study clusters [11].

Some challenges exist in categorizing critical pregnancy outcomes. For example, when birth occurs at home unattended by a skilled birth attendant, the proper classification of intrapartum stillbirth versus very early neonatal death [14] and macerated versus non-macerated stillbirth are particularly challenging [15]. Finally, determining accurate birth weights of certain groups of infants is difficult. The weight of stillbirths is often not possible to obtain because weighing a dead infant is not culturally acceptable in many communities. Acquiring an accurate birth weight of a live-born infant delivered at home is often difficult because the infant cannot be weighed within a sufficiently brief period after birth. To overcome this challenge, strategies have included home visitation and providing village chiefs with scales [12].

Discussion and Conclusions

Developing public policy and improving public health in countries with poor perinatal outcomes is, in part, dependent upon understanding the outcome of every pregnancy. Because the worst pregnancy outcomes typically occur in countries with limited health registration systems and vital records, alternative registration systems may prove to be highly valuable in providing data. One alternative is a survey system, such as the Demographic and Health Survey (DHS). The DHS has conducted surveys in more than 90 low- and middle-income countries since 1984 [30]. It is widely used for country comparisons but is handicapped in this capacity because it is often adapted by individual countries to suit national needs for specific data [31]. By contrast, the MNHR has the advantage of using the same data set, data gathering techniques and standard definitions across all sites. The MNHR also is an ideal tool for evaluating the effectiveness of strategies of care because, unlike with the use of periodic surveys, data is collected continuously over time within the same population-based cohort. This enables investigators to determine the impact of interventions to improve outcomes, to monitor trends over time, and to evaluate the changing patterns of perinatal care to inform health policy.

In this supplement, there are a series of manuscripts that highlight the utility of the MNHR [10,11,18-27]. They include manuscripts that describe processes of care that define the quality of antenatal care and major pregnancy outcomes, both among all women enrolled in the MNHR and in selected groups (e.g. adolescent mothers). Finally, problems and outcomes unique to single sites are explored.

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Peer review

Reviewer reports for this article can be found in Additional file 1.

Additional material

Additional file 1:

List of Abbreviations
NICHD: *Eunice Kennedy Shriver* National Institute of Child Health and Human Development; MNHR: Global Network Maternal Newborn Health Registry; HDI: Human Development Index; DCC: Data Coordination Center; RA: research administrator traditional birth attendant; LMP: last menstrual period; WHO: World Health Organization; TBA: traditional birth attendant; DHS: Demographic and Health Survey

Competing Interests
The authors have no competing interests.

Authors' contributions
CLB developed the content outline and first draft of the manuscript.
MB developed sections of the manuscript and edited its content.
EMM assisted with reporting of data and edited the content.
RLG, SSG, OP and WAC edited the content. AG edited the content and provided country-specific HDIs.
JM provided data for tables and other facts describing sites.
MK-T and MM edited the content.
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