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Maternal and perinatal health research during emerging and ongoing epidemic threats: a landscape analysis and expert consultation

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ABSTRACT

Introduction Pregnant women and their offspring are often at increased direct and indirect risks of adverse outcomes during epidemics and pandemics. A coordinated research response is paramount to ensure that this group is offered at least the same level of disease prevention, diagnosis, and care as the general population. We conducted a landscape analysis and held expert consultations to identify research efforts relevant to pregnant women affected by disease outbreaks, highlight gaps and challenges, and propose solutions to addressing them in a coordinated manner.

Methods Literature searches were conducted from 1 January 2015 to 22 March 2022 using Web of Science, Google Scholar and PubMed augmented by key informant interviews. Findings were reviewed and Quid analysis was performed to identify clusters and connectors across research networks followed by two expert consultations. These formed the basis for the development of an operational framework for maternal and perinatal research during epidemics.

Results Ninety-four relevant research efforts were identified. Although well suited to generating epidemiological data, the entire infrastructure to support a robust research response remains insufficient, particularly for use of medical products in pregnancy. Limitations in global governance, coordination, funding and data-gathering systems have slowed down research responses.

Conclusion Leveraging current research efforts while engaging multinational and regional networks may be the most effective way to scale up maternal and perinatal research preparedness and response. The findings of this landscape analysis and proposed operational framework will pave the way for developing a roadmap to guide coordination efforts, facilitate collaboration and ultimately promote rapid access to countermeasures and clinical care for pregnant women and their offspring in future epidemics.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Previous epidemics and pandemics highlighted the dearth of preparedness and response for maternal and perinatal health, resulting in delayed access to countermeasures for pregnant women and their offspring, despite them often being identified as a group at increased risk of severe disease outcomes.

⇒ Existing literature evaluates gaps in approaches for alleviating gender inequality in future public health emergencies and the impacts of the COVID-19 pandemic on maternal and perinatal health services

WHAT THIS STUDY ADDS

⇒ This study provides a comprehensive overview of existing research efforts and key areas of focus relevant to maternal and perinatal health, identifying current gaps and exposing shortcomings in existing infrastructure. It proposes an operational framework for improving conduct of maternal and perinatal heath research in the context of emerging and ongoing epidemic threats.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings of this landscape analysis and proposed operational framework will pave the way for developing a roadmap to guide coordination efforts, facilitate collaboration and ultimately promote rapid access to countermeasures and clinical care for pregnant women and their offspring in future epidemics.

INTRODUCTION

The likelihood of infectious disease outbreaks, epidemics and pandemics is increasing and is expected to triple over the coming decades,[1] due to a number of contributing factors such

as increased travel, urbanisation and climate change.[2] Historically, the emergence of epidemic-prone diseases, including Ebola, Zika and respiratory infections such as severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS) and influenza A/H5N1 and A/H1N1 has caused global panic and alarm. However, disease emergence has often been followed by underinvestment in capacity strengthening, integrated surveillance and protection of populations during the recovery phase.[3] In this context, the ability to quickly gather information on the natural course of disease progression, clinical characteristics and pathophysiology is necessary for the development of prevention and clinical care strategies and guidelines, as well as for the planning, design and delivery of care.[3]

Preparedness is key to reducing the impact of future disease outbreaks, and there are a number of lessons to be learnt from the experience of the COVID-19 pandemic, where prepandemic response planning was limited, and handling of the health emergency at the global level was a considerable challenge.[4] In the aftermath of the pandemic, the international community has called for strengthening of health emergency preparedness, response and resilience architecture[1] to better understand the distribution of priority emerging infectious diseases, together with drivers of transmission, natural history, clinical characteristics, and disease pathophysiology. This can help guide preparedness planning and strengthen health systems to ensure that they can effectively anticipate, respond to and recover from the impacts of any health emergencies.[3] Integral to this response is the WHO Research and Development (R&D) Blueprint, which brings together key stakeholders to identify gaps and accelerate research for accurate diagnostic assays, novel therapeutics and effective vaccines against priority pathogens.[5–7]

It is now globally recognised that a comprehensive research response to emerging and ongoing epidemic threats can and should contribute to improve our understading of how these affect health and access to healthcare for women and children, in addition to their social and economic burden.[3] Often, subpopulations, such as pregnant women and their offspring, are at higher risk both directly from the disease and from indirect factors. For example, pregnant women may be more likely to experience severe disease compared with non-pregnant women, as was noted during the COVID-19 and the 2009 influenza pandemics,[8 9] or their offspring may be at increased risk for developmental abnormalities, such as the association between microcephaly and maternal Zika infection observed during the 2015 outbreak in Brazil.[10 11] In addition to direct disease effects, pregnant women and their offspring are likely to be impacted by indirect effects, such as decreased access to maternity services, and increased childcare demands on working mothers during lockdown situations.[12 13] Furthermore, pregnant women are generally excluded from clinical trials of medicines and vaccines, resulting in delayed access to potentially life-saving treatments or preventative interventions.[14–17]

Our objective was to evaluate the current maternal and perinatal research landscape and identify major gaps and challenges to delivering a coordinated and rapid research response to emerging and ongoing epidemic threats. We present the integrated findings of a landscape analysis, discussions with key informants (KIs) and outcomes of two expert consultations. We also propose an operational framework for maternal and perinatal research to be applied during ongoing and emerging epidemic threats.

METHODS

This landscape and gap analysis involved compilation and description of current research efforts relevant to maternal and perinatal health during ongoing and emerging epidemic threats. As such, it formed the basis for a series of consultations to further identify main challenges and opportunities for coordination and generate ideas of how current research efforts could be leveraged to address gaps. These supported development of an operational framework for improved maternal and perinatal health research during epidemics and pandemics. A steering committee was established to oversee and provide technical guidance at various stages of the project.

Landscape and gap analysis

Desk review: search strategies and selection criteria

Initial searches were performed on Web of Science from 1 January 2015 to 22 March 2022 using three search strings including population (eg, maternal/pregnancy), topic area (eg, COVID-19, other infections) and methodology (eg, various study designs) (see online supplemental material 1). Where the initial publications referenced other relevant publications, research networks or authors, Google Scholar and PubMed were examined (using the same key search terms) to ensure completeness of the searches. In parallel, a similar search was performed across grey literature, including governmental websites, relevant non-governmental and international organisations, conference proceedings, clinical trial registers, existing research effort websites and associated networks' sites, as well as targeted Google searches.

A research 'effort' was defined as a persistent data generation or aggregation exercise, which could be an individual study or a network or collaboration. Search results were filtered to exclude efforts considered to be beyond the scope of the study (eg, only testing interventions in neonates) or focused on multiyear/lifelong longitudinal cohort studies' or those that had otherwise been terminated. Broader efforts, such as the WHO Programme for International Drug Monitoring[18] and ISARIC network,[19] were also excluded.

Preliminary findings from the literature review, grey literature and interviews were filtered against these screening criteria through manual review. The retrieved

articles were screened by title and abstract to single out relevant full-text documents to be evaluated against the inclusion criteria. A data extraction form was used to extract information on the characteristics of those efforts (see online supplemental material 2), as well as opportunities and challenges pertaining to maternal and perinatal health research during epidemics and pandemics. What remained at the end of the filtering process was included in the landscape analysis.

Preliminary contacts with KIs

KIs were selected among the members of WHO steering committee, principal investigators or network members of efforts identified through the literature search. In total, 23 experts were contacted to identify further research efforts, gather more information on efforts led by KIs and gain insights on opportunities and challenges for collaboration.

Quid analysis

Findings of the literature search described above were validated using Quid (Quid, Business Intelligence Software, http://quid.com), an artificial intelligence software. The results were cross-checked and tested via Quid analysis to address biases and cover blind spots. This analysis allowed for finding gaps in the research landscape and clustering authors and research focuses and topics (eg, Zika, birth and morbidity) to detect networks and key individuals linking efforts, and to identify disparate, poorly linked clusters for which further investigation and outreach might be needed.

Synthesis of findings

Associated study publications, protocols and websites were reviewed to determine the population scope (eg, maternal, neonatal, both or general population), the region where the effort was active, operational period (research duration), type of research focus (eg, observational, interventional, surveillance) and topic area (eg, morbidity, outbreak/epidemic). Results of desk research and expert interviews were used to evaluate research efforts and better understand the full scope of activities and related publications. When there was evidence of previous pandemic and epidemic-related work, emergency focus was included as part of the research scope. Furthermore, key networks of clusters and authors serving as connections were visually identified using Quid analysis. To gain additional understanding, a deeper characterisation of selected efforts (exemplars) across a range of geographies and types was conducted. Key themes emerging from interactions with KIs were also identified and used to inform subsequent technical consultations.

Technical consultations

Two expert consultations were conducted in June 2022 and May 2023 to reflect on the results of the landscape analysis, learn from challenges and opportunities of exemplars, discuss an operational framework, and identify needs and next steps to produce concrete and actionable outputs for improved maternal and perinatal health research during epidemics and pandemics. A total of 33 attendees with broad expertise and relevant clinical and academic experience attended the meetings. Among them, 22 were women and 11 were men; 11 experts came from low-income and middle-income countries (LMICs) while the remaining 22 experts represented high-income countries (HICs), most with direct experience in coordinating or supporting research in Africa, Asia and Latin America. In terms of the geographical representation of the WHO regions, 3 people came from Africa, 15 from the Americas, 2 from Eastern Mediterranean, 10 from Europe, 2 from South-East Asia and 1 person from the Western Pacific.

RESULTS

Overall, literature searches identified 3023 unique articles which were reviewed to identify relevant efforts corresponding with agreed definitions. Some articles yielded multiple efforts, while others yielded none. At the end of this process, a total of 94 research efforts considered relevant for maternal and perinatal health research during future outbreaks were identified (see online supplemental material 3). The landscape analysis and expert consultations yielded three key findings leading to the development of an operational framework.

Finding 1: substantial research efforts exist; there is sufficient infrastructure to support robust maternal and perinatal health research during outbreaks mainly in high-income settings

Multiple relevant research efforts are already in place. In total, 83% (78/94) of research efforts focused predominantly on both maternal and neonatal health (figure 1A), with few efforts in the general population also including pregnant populations (2%, 2/94). These efforts have a broad geographical distribution, with 33% (31/94) being global efforts, 38% (36/94) originating from Europe or North America and 29% (27/94) originating from the rest of the world (figure 1B). Considerably fewer efforts were identified in Latin America, and there were no efforts solely based in the Eastern Mediterranean region. Data on duration were available for 81 research efforts, with the majority (60%) being operational for more than 5 years and 19% for more than 25 years (figure 1C). Many of these efforts had been successfully used during the COVID-19 pandemic by leveraging existing protocols and clinical trials to collect data on COVID-19 burden, pregnancy outcomes and use of medicines in pregnancy.[20–22]

Quid analysis showed that the over 3000 articles identified were authored by more than 20 000 researchers, in research networks consisting of more than 65 000 specific collaborations. Overall, the research ecosystem was predominantly comprised of discrete small clusters of research, with few connections (online supplemental figure 1a). In total, 31 clusters included 0–5 authors, 10

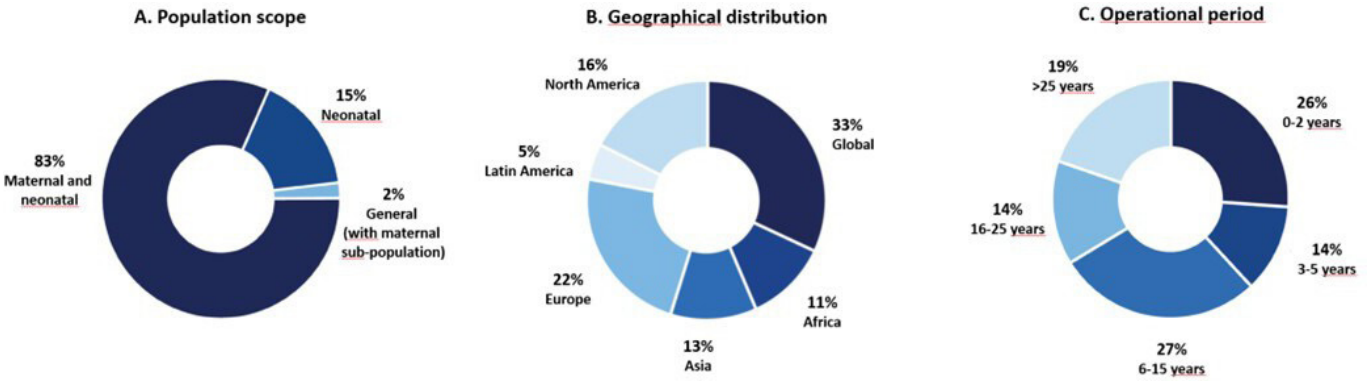

Figure 1 Characteristics of research efforts identified through literature searches and expert consultations.

included 6–10 authors and 11 included >10 authors. The most connected networks contained several of the largest clusters (online supplemental figure 1b). The research landscape covered 16 major maternal and perinatal health topics, the most common being low-resource challenges (11%), diet and nutrition (11%) and vaccinations (12%; Online supplemental figure 1c).

Existing multicountry or regional networks may be the fastest path to improving maternal and perinatal health research during outbreaks. Large multicountry or regional networks already exist across epidemiology, research and development, postauthorization surveillance and advocacy. The International Network of Obstetric Survey Systems (INOSS) (https://www.npeu.ox.ac.uk/inoss), the Global Network for Women's and Children's Health Research (https://globalnetwork.azurewebsites.net/),[23] HIV/AIDS Clinical Trials Units and Clinical Research Sites (https://www.niaid.nih.gov/research/hivaids-clinical-trials-units-and-clinical-research-sites) and NEOCOSUR (https://neocosur.uc.cl/neocosur/vista/index.php) are already coordinating research and enabling collaboration on randomised controlled trials and observational studies. Multisite networks increase access to larger and more diverse study populations, which in turn increases the generalisability of study findings. In addition, alignment and coordination within networks can allow prompt cascading of new studies, protocols or interventions to smaller satellite sites, which would not have been possible without cooperation within and among networks.

Finding 2: existing infrastructure is best suited to provide epidemiological data; R&D including pregnant women during outbreaks is limited

Approximately 87% of the identified efforts are suited to support rapid generation of epidemiological data, 14% postauthorization surveillance data, whereas only 9% focus on research and development of interventions. Many efforts conducted activities that contributed towards multiple categories (eg, epidemiology and product development research).

Observational epidemiological efforts are suitable for rapidly leveraging the current infrastructure to describe the disease characteristics in outbreaks, epidemics and pandemics. Efforts such as the UK Obstetric Surveillance System (UKOSS),[20] INOSS,[24] the Global Network Maternal Newborn Health Registry,[23] INTERCOVID[25] and MA-Cov[26] successfully adapted existing platforms during the COVID-19 pandemic. Still, certain barriers remain, such as the speed of ability to amend existing protocols. Relatively few efforts focused on development of interventions, and the majority centred on repurposing existing interventions rather than introducing novel ones. For example, excluding women from clinical trials resulted in a significant research gap during the COVID-19 pandemic,[14 15] although there were efforts that advocated for improving inclusion of pregnant women in clinical trials (eg, ConcePTION[27]). Furthermore, significant barriers to inclusion of pregnant women in clinical trials persist for developers of medical products, ranging from perceived higher levels of legal liability and reputational damage to unknown risks to the pregnant woman and the fetus. At the same time, relatively few incentives are available, despite the existence of guidance supporting inclusion of pregnant women in clinical trials.[16 28 29]

Finding 3: limitations in global governance, coordination and funding, and established data-gathering systems, cause delays in prompt, broad activation of research efforts during outbreaks

Establishing governance, coordination and funding plans at the time, rather than in advance, of emergencies such as the Zika virus disease outbreak and COVID-19 pandemic delayed generation of evidence critical to determining the burden of disease and guiding public health policies and clinical management. For example, most of the maternal and newborn health efforts during the Zika outbreak occurred after cases had peaked, therefore, missing critical periods for data collection and evidence generation for clinical decision-making. Efforts that required de novo development of studies and data-gathering systems, including protocols, ethics approvals, data sharing agreements, etc, responded more slowly than those that had these structures in place. Studies which leveraged existing protocols and systems (eg, UKOSS,[20] Zika in Pregnancy in Honduras[30] and INTERCOVID[25] studies) during the COVID-19 pandemic resulted in more

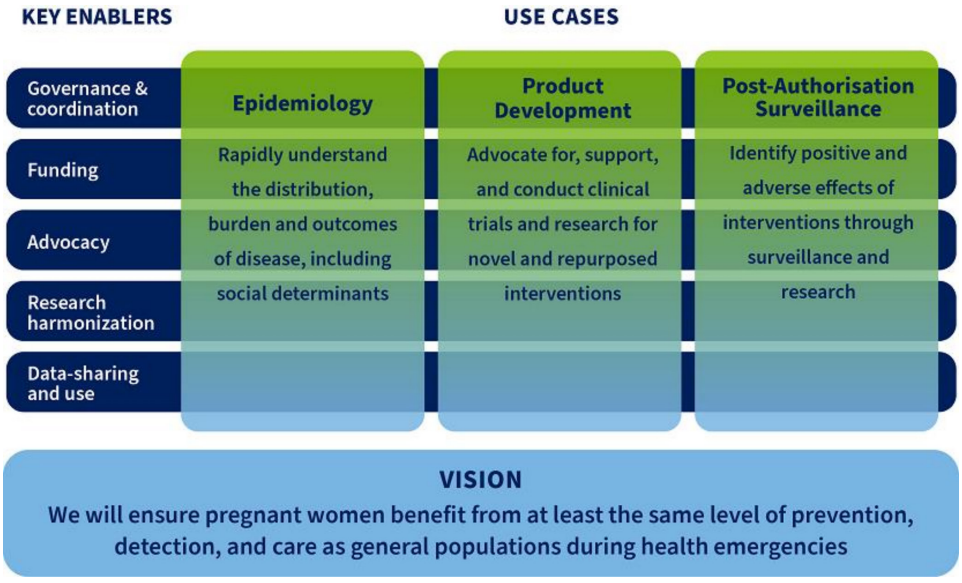

Figure 2 Operational framework for maternal and perinatal health research during emerging and ongoing epidemic threats.

rapid generation of epidemiological data compared with those studies developed and launched after COVID-19 had already emerged. These existing research efforts would benefit from increased global coordination, including harmonisation of research protocols and preagreed data-sharing agreements and data analysis plans, to generate robust data that is applicable on an international scale. Specific funding to improve preparedness for research in pregnancy is not readily available, and many research efforts still struggle to obtain baseline funding. Funding for generating data concerning pregnant women is scarce and many research efforts are unable to secure and sustain baseline funding. It should be noted that prior to the COVID-19 pandemic, minimal investment was made for emergency preparedness and coordinated response, yet individual efforts (eg, vsafe,[31] UKOSS[20]) received funding from emergency response.

Operational framework for maternal and perinatal health research during emerging and ongoing epidemic threats

The operational framework (figure 2) features three use cases (epidemiology, product development and postauthorisation surveillance) that address the key gaps identified in the landscape review and expert consultations. The ability to generate epidemiological data on distribution, risks and burden of disease, and to facilitate its use for informed response, clinical guidance and to enable prompt development of interventions is key. Conduct of trials that involve pregnant women where appropriate should support equitable development, access to and utilisation of interventions. Properly conducted postauthorisation surveillance activities would allow generation and communication of findings about the benefits and adverse effects of the use of medical products to further inform and update policy and practice.

The three use cases supported by five key enablers (governance and coordination, funding, advocacy, research harmonisation, data sharing and use) reflect interrelated actions that are needed to improve research and decision-making related to pregnancy during ongoing and existing epidemic threats. Good governance and enhanced coordination mechanism are necessary to enable, guide and oversee rapid research response encompassing research analyses and prompt dissemination of findings. Addressing health emergencies in a timely manner requires the presence of well-functioning sites and a pool of trained personnel. Researchers in maternal and perinatal health should work hand in hand with public health administrators, policy-makers and regulators on methods and data to be collected and shared in a manner that allows for informing policy and practice. The coordination mechanism should leverage existing platforms, ensuring that work is complimentary to and aligned with other preparedness initiatives directed at the general population. Establishing 'centres of excellence' or 'sentinel sites' should be supported as it would help close some of the existing gaps. Finally, opportunities ought to be created for research collaboration to continue at times when there are no outbreaks to maintain the existing infrastructure and promote continuous capacity building, particularly in low-resource settings.

In the initial phase, some funding would be required to establish major components of coordination and catalytic preparedness activities centred around capacity building, advocacy, harmonisation, and data sharing and use. Incremental funding would help maintain research readiness and research implementation during outbreaks, encompassing data collection, publication and dissemination, and translation of findings into policy and recommendations. There is a need to map funding opportunities and proactively engage with donors to promote preagreed funding priorities and mechanisms.

Building and maintaining relationships with key stakeholders to encourage continuous interest in

involving pregnant populations in research would be an important enabler. Key stakeholders include researchers, health security and epidemiological surveillance actors, governments, policy-makers, industry, regulators, patient groups, and civil society representatives, among others. High-profile advocacy is needed to remove barriers to research concerning pregnant women. Collaboration with pharmaceutical companies, who are often disincentivised from involving pregnant women in clinical trials, is needed to better understand and address their concerns. Underlining the ethical aspects could substantially help in facilitating the inclusion of pregnant women in trials while encouraging the use of medical products in pregnancy, and disaggregation of epidemiological and surveillance data by pregnancy status. Another suggestion was to develop best practice guidance for community engagement and research, which would lead to meaningful engagement of women and civil society in epidemic and pandemic research. This covers efforts related to the dissemination of results and promotion of uptake of medicines and vaccines once those have been proven to be safe and effective. Advocating for the 'general' pandemic funding to include sexual and reproductive health funding is advisable as it would serve to ensure that other emergency preparedness efforts launched in the wake of COVID-19 pandemic consider pregnant women's needs.

Finally, equitable approaches should be used for development and implementation of research and data sharing, and to obtain relevant ethics and regulatory approvals in a timely manner and using a risk-proportionate approach. Harmonisation of approaches, as opposed to complete standardisation across sites, is highly desirable. It would enable rapid research response, minimising delays to data collection, support rapid generation and synthesis of data, by addressing inconsistencies in outcome selection, measurement, and reporting. This entails development of harmonised research protocols for population-based epidemiological studies, clinical trials and postauthorisation surveillance based on an agreed set of core variables/outcomes and definitions, including patient-centred outcomes, preagreed global data sharing principles, authorship rules and publishing principles, in accordance with international regulations. A mapping and analysis of existing protocols, data analysis plans and data sharing agreements would inform development of standard procedures applicable across different countries and networks. This would serve to improve the availability of harmonised research tools and help streamline ethical review and approval processes while promoting data sharing and use by clinicians, regulatory authorities, policy-makers and others. Establishing fair agreements, including for sharing and using unpublished data, that consider the interests of countries and allow for research capacity building, while safeguarding those sharing data and study participants is crucial.

Patient and public involvement

Patients were not involved in the design and conduct of the landscape analysis or expert consultations. Results of an ongoing systematic review on patient and public involvement in maternal and perinatal health research in LMICs were discussed at the expert consultation in June 2022.

DISCUSSION

This landscape analysis and consultative process identified 94 current research efforts applicable to maternal and perinatal research during emerging and ongoing epidemic threats. It further supported developing a better understanding of limitations and challenges to deliver a more coordinated and rapid research response on maternal and perinatal health during outbreaks. Many gaps were identified, ranging from clustered efforts towards epidemiological research to the need to scale up efforts related to R&D of medical products including pregnant women. In certain geographies, particularly in Latin America and Eastern Mediterranean, scarcity of research efforts was observed. Other regions suffered from lack of coordination, poor governance, insufficient funding and limited harmonisation of research and data sharing. An operational framework for improved maternal and perinatal health research has been proposed to address all those gaps. It spans across three 'use cases' (epidemiology, product development and postauthorisation surveillance) supported by five key enablers (governance and coordination, funding, advocacy, research harmonisation, and data sharing and use). The use cases would be ready for rapid deployment as per required geographical scope of an outbreak, thus allowing for a timelier decision making by policy-makers, health workers and pregnant women themselves.

While some global efforts covered all regions, the analysis revealed clustering of research towards certain regions and specific use cases. Yet, despite recent outbreaks of Zika, chikungunya and dengue relatively few research efforts were found in Latin America and that is concerning. Similarly, no efforts were identified in the Eastern Mediterranean where MERS first appeared. Going forward, a well-designed research infrastructure should be established and maintained in all regions to generate data as soon as the need arises. Although, our search strategy maximised identification of active research studies, networks and collaborations, from 2015, we may have missed some relevant research efforts. However, our findings showed that earlier research efforts, particularly those that emerged in response to respiratory diseases, were either discontinued or repurposed in the wake of the COVID-19 pandemic.

Ongoing efforts focused largely on collecting epidemiological data and relatively few efforts centred on product development in pregnant women. Global collaborative research networks that use harmonised protocols and simplified data collection systems have accelerated

the process of evidence generation.[32] Maintaining and expanding these research networks will help accelerate the response to future epidemics.

Epidemiological efforts will be vital for providing data on risks and outcomes during ongoing and emerging epidemic threats, and informing development of clinical trials and postauthorisation efforts that will encompass the population of pregnant women. Yet, additional engagement of stakeholders is desirable as it would help increase advocacy for appropriate inclusion of pregnant women in product development while allowing for a more rapid product delivery to this population in an emergency context. During the COVID-19 pandemic, a large number of clinical trials of selected vaccines and therapeutics systematically excluded pregnant women,[33] while many of the products under evaluation had none or very low safety concerns during pregnancy.[14 15] Barriers for inclusion of pregnant women in trials persist, despite continuous calls for generation of efficacy and safety data during pregnancy in the context of outbreaks.[16 33 34] The lack of such clinical trial data hampers guideline development and public health advice. Ethical and regulatory frameworks and mechanisms defining when and how subpopulations such as pregnant women and children can and should be enrolled in clinical trials are needed to better address their needs. Currently, various guidance documents are being updated or developed at the international and national level, but none is specific to pregnancy research in the context of emerging and ongoing epidemic threats.

In contrast, effective networks and research studies are already underway or in place for conducting postauthorisation surveillance across many regions and they can be used during future outbreaks. Expanding them to cover additional geographies would provide a robust global picture of postauthorisation safety and allow for a rapid identification of any concerning signals in pregnant women or their offspring. The efforts potentially relevant to an emergency response identified in this landscape analysis fit into a broader landscape, which includes 8 maternal and neonatal data collection systems in LMICs,[35] over 170 pharmacovigilance organisations globally,[18] and 52 clinical trial networks focused specifically on infectious diseases, including in LMICs.[19]

Another gap that was identified referred to insufficient governance and lack of funding, leading to uncoordinated and slow research responses on maternal and perinatal health during epidemics and pandemics. Established sites, trained personnel and alignment among stakeholders are necessary for a coordinated emergency response which promotes inclusion of pregnant women in clinical trials, harmonises messaging and achieves a maximal impact within the resources available. Outside of epidemic and pandemic situations, the framework provides the potential to expand research focusing on pregnant women and their offspring at the global and regional level, allowing for an increased focus on other maternal and child health priorities. In addition, it serves to promote greater collaboration among research groups and institutions resulting in copublication of baseline data to be used by decision-makers as needed. Advocacy efforts underscore the importance of engaging pregnant women in research so that their needs are more likely to be considered in epidemic or pandemic situations. Stakeholder engagement is one of the key elements in achieving the vision of pregnant women benefiting from at least the same level of prevention, detection and care as the general population during epidemics and pandemics. This maximises preparedness to ensure that this group would not be left behind in the future.

In summary, this landscape analysis and associated consultations identified numerous gaps that should be addressed to improve generation of data on maternal and perinatal health, and inform timely decision-making by policy-makers, health workers and pregnant women themselves, particularly in LMIC settings. Having explored how existing maternal and perinatal health research platforms could be leveraged to address existing gaps and how they could be used to meet the need for a comprehensive global emergency response, it was determined that structures and mechanisms would need to be established to approach dealing with new epidemics or pandemics in a holistic and coherent manner. Using an operational framework based on three use-cases and five supporting key enablers, the WHO/Human Reproduction Programme aims to develop a roadmap to guide maternal and perinatal health research, facilitate data consolidation to enable faster decision-making and support readiness building. Efforts have already started and should be expanded for harmonisation of research protocols, and development of core outcomes to be collected for measuring maternal and perinatal health during future outbreaks.

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Contributors MBonet and OTO conceptualised the study; JM and HS conducted the desk review; UC and MW conducted Quid analysis; MBonet, MBabinska, OTO, JB, SC, ES, AS, JM and HS coordinated the expert consultations. Members of the HRP Steering Committee (PB, SSG, BK, MK, DM-D, SL, FMR, AS and CT) made significant contributions to the manuscript and facilitated preparations for the expert consultations in which they also participated. MBonet and MBabinska drafted the manuscript with support from a medical writer. All authors provided comments and approved the final version of the manuscript. MBonet is the guarantor.

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Competing interests BK is a former member of Scientific Advisory Board of Pfizer and a current member of Data Safety Monitoring Board at J&J. Her employer received a grant from Pfizer. MK is a recipient of grants awarded to the institution by the National Institute for Health Research Healthcare Quality Improvement Programme. FMR is a member of Moderna's Vaccine Safety Monitoring Board and Pfizer's and Meissa's Data Safety Monitoring Board (RSV vaccines) and Dynavax (plague vaccines). She has received grants awarded to her institution from NIH & CDC for COVID-19 vaccines and respiratory viruses epidemiology, Pfizer for COVID-19 vaccines and Gilead for remdesivir. Aside from being compensated for conducting reviews, FMR receives author royalties and consulting fees from Sanofi, Astra Zeneca, Merck and Moderna related to the prevention of viral respiratory infections. AS has received grants from USAID and BMGF which were awarded to his institution. He is a non-compensated member of Data Safety Monitoring Board/Advisory Board of IMPROVE (malaria chemoprevention) Trials and INTREPiD (malaria testing). AS also sits on Safety Platform for Emergency Vaccines (SPEAC) Executive Board and the Scientific Advisory Board of Vivli AMR Register in addition to receiving consulting fees from CEPI and PATH. CT receives support from Harvard School of Public Health, Yale School of Public Health, and the Pan American Health Organization. All other authors declare no competing interests. The collaboration between The Human Reproduction Programme (HRP), Department of Sexual and Reproductive Health, WHO and Research and Bill & Melinda Gates Foundation is governed by a bilateral agreement.

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Supplementary Materials

Supplementary Material 1. Search strategy in Web of Science

TI=(maternal OR neonatal OR "neo-natal" OR "neo natal" OR pregnancy OR pregnant OR gestation* OR prenatal OR "pre natal" OR "pre-natal" OR perinatal OR "peri natal" OR "peri-natal" OR mothers OR "mother baby" OR "mother-baby" OR neonates OR lactat* OR "post-natal" OR "postnatal" OR "childbirth" OR "newborn")

AND

AB = (immuniz* OR vaccin* OR epidem* OR pandemic* OR endemic* OR "infectious" OR "nutrition" OR efficac* OR "influenza" OR "flu"OR coronavirus* OR covid OR "covid-19" OR zika OR ebola OR "SARS-CoV" OR "MERS-CoV")

AND

AB=(longitudinal OR "population-based" OR "population based" OR "population data" OR "cohort study" OR "cohort studies" OR surveillance* OR "post-marketing" OR "post marketing" OR "observational")

NOT

TI=(meta-analysis OR qualitative)

Supplementary Material 2. Data extraction form

Site / network	[Name]
Links	[Name of PoC]
Brief Description	[Free text, covering background and aim of study]
Categorisation	[Type of study, emergency vs non-emergency focus, general vs maternal, interventional vs observational]
Scope	[Free text covering topics including disorders / diseases etc.]
Geography	[Countries and regions of surveillance]
Sample Size	[enrollment rate, # of pregnant women, deliveries registered etc.]
Lab capacity / capability	[Free text covering e.g., PCR capability, bio-safety levels etc.]
Protocols & mechanisms for amendments, including hard outcomes	[Free text covering e.g., detailed instructions on methodology, outcomes measured, reporting processes, cadence, identification and how to amend protocols etc.] [Y/N against outcomes measured, including spontaneous abortion/miscarriage (10-19 wks gestation), stillbirth, preterm birth (<28wks, <32wks), low birth weight, NICU admission, maternal death, neonatal mortality (28 day)]
Other data priorities	[Free text]
Data collection	[Free text covering type of platforms, license & database, policies around data privacy & protection and definition of outcomes, + Y/N against ability to share and integrate data]
Funding & governance	[Free text covering sponsor / funding, institutions in charge of dev. / updates, cost for emergency research]
Emergency response	*[Free text covering any emergency response work currently conducted, and potential to pivot to emergency response in future]*
Opportunities	*[Free text covering any advantages of the site / network e.g.speed, practical use of data etc.]*
Challenges	*[Free text covering challenges e.g.funding for emergency response, comparison group, deidentified info etc.]*

Supplementary material 3. Research efforts identified in desk review

Effort (s)	Brief descriptions
AlignMNH	AlignMNH is a global initiative funded by the Bill & Melinda Gates Foundation in collaboration with the United States Agency for International Development. The initiative was founded in 2020 to accelerate progress in improving maternal and newborn health outcomes and prevent stillbirths around the globe. AlignMNH is supported by a Secretariat, managed by Jhpiego, an international NGO focused on transformative health care solutions that save lives. AlignMNH works in partnership with global and country-based organizations, national-level technical working groups, and other MNH-focused initiatives to more rapidly share science, evidence and programmatic experience across the maternal and newborn health communities
Alliance for Maternal and Newborn Health Improvement (AMANHI) Study	The Alliance for Maternal and Newborn Health Improvement (AMANHI) study in Sylhet district, Bangladesh, is using ongoing newborn intervention trials to obtain data critical to maternal, fetal and newborn health
Australasian Maternity OutcomesSurveillance System (AMOSS)	The Australasian Maternity Outcomes Surveillance System (AMOSS) is a national surveillance mechanism designed to study a variety of rare orserious conditions in pregnancy, childbirth and the postnatal phase in Australia and New Zealand. Through translating the findings from thesestudies into reliable evidence-based practice, the aim of AMOSS is to improve the safety and quality of maternity care in Australia and New Zealand
Australia and New ZealandNeonatal Network	The Australian and New Zealand Neonatal Network (ANZNN) is a collaborative network that monitors the care of high risk newborn infants by pooling data to provide quality assurance for this resource consuming care. The network was established in 1994 under the recommendation of the National Health and Research Council's (NHMRC) Expert Panel on Perinatal Morbidity. Since its establishment the network has developed a minimum data set and implemented a data collection that monitors the mortality and morbidity of infants admitted to neonatal intensive care units across Australia and New Zealand
Austrian obstetric surveillancesystem (AuOSS)	This is an obstetric surveillance system in Austria
Belgian Obstetrics Surveillance System (BOSS)	The Belgian Obstetric Surveillance System (B.OSS) was launched in 2011 with the support of the College of Physicians for Mother and Newborn of the Federal Public Service Public Health.B.OSS investigates serious complications that occur during pregnancy or childbirth and that put the life of the mother and/or the unborn child at risk. These are rare complications that affect less than one out of 2,000 women
BetterBirth Program	The BetterBirth Program is a project of the Ariadne Labs focused on ensuring better health and wellbeing for women, newborns, and infantsby improving quality and standards of care, minimizing complications, and ending preventable deaths. They do this through the implementation of scalable, evidence-based solutions that work in the real world, both at the frontline of care and in communities. The BetterBirth Program began with the goal of evaluating the World Health Organization’s (WHO) Safe Childbirth Checklist and identifying opportunities and strategies to support its successful implementation. Since that time, it has grown to address the complexities across the ecosystem of maternal, newborn, and infant health
Brazilian Obstetric Observatory (OOBr)	The objective of this project is to create an obstetric observatory through an interactive platform for monitoring, analyzing public data and disseminating information in the area of Obstetrics in Brazil. It will provide exploratory data analysis with the purpose of assessing the

	impacts of the H1N1 (2009) and COVID-19 (2020) pandemics on maternal, fetal and neonatal health
Canadian Neonatal Network	This is a group of researchers who collaborate on research issues relating to neonatal care with members from 30 hospitals and 17 universities. It maintains a standardized neonatal intensive care unit (NICU) database and provides a unique opportunity for researchers to participate in collaborative projects on a national and international scale; supports clinical, epidemiologic, outcomes, health services, health policy and informatics research aimed at improving efficacy and efficiency of neonatal care
Canada (CanOSS)	This is an obstetric surveillance system collecting data from Canada. It is a partner of INOSS
CatOSS	This is an obstetric surveillance system collecting data from Spain. It is a partner of INOSS
CHAMPS	The Child Health and Mortality Prevention Surveillance Network (CHAMPS) was established to develop a network of high-quality sites to collect robust and standardized longitudinal data, with the overarching objective of understanding and tracking the preventable causes of childhood death globally.
CMC Vellore	They have a surveillance study that collects risk factors and outcomes of pregnant women every 4 months via cross sectional surveys, home visits and a longitudinal study that investigates data on key maternal and infant health indicators.
ConcePTION project	ConcePTION is a 5-year program by funded by the Innovative Medicines Initiative. It is a research consortium aimed at establishing an international network and framework to improve the evaluation of the safety of medicines in pregnancy and breastfeeding. It represent 88 public and private organisations
Coronavirus Health Outcomes inPregnancy and Newborns	The CHOPAN registry aims to collect real-time data on pregnant women who are infected with the coronavirus that causes COVID-19 (SARS-CoV2) to improve understanding of its impact on pregnancy outcomes. This registry provides regular feedback to clinicians and public health officials to allow evidence-based management of women and their babies with coronavirus infection. This registry was developed by Australian clinicians in collaboration with international colleagues in order to maximise its value to the global community
COVID-19 in pregnancy(PregCOV-19LSR)	The PregCOV-19 project aims to undertake living systematic reviews (LSR) involving pregnant and postnatal women at risk, suspected, and diagnosed to have COVID-19, and synthesise the relevant evidence on prevalence, risk factors, mother-to-child transmission, diagnosis, treatment of the disease. The findings will be continuously updated, by incorporating appropriate new evidence as it becomes available
COVID-19 Vaccines International Pregnancy Exposure Registry (C-VIPER)	The objective of the COVID-19 Vaccines International Pregnancy Exposure Registry (C-VIPER) is to evaluate obstetric, neonatal, and infant outcomes among women vaccinated during pregnancy with a COVID-19 vaccine. They measure obstetric outcomes (spontaneous abortion, antenatal bleeding, gestational diabetes, gestational hypertension, intrauterine growth restriction, postpartum hemorrhage, fetal distress, uterine rupture, placenta previa, chorioamnionitis, Caesarean delivery, COVID-19), neonatal outcomes (major congenital malformations, low birth weight, neonatal death, neonatal encephalopathy, neonatal infections, neonatal acute kidney injury, preterm birth, respiratory distressin the newborn, small for gestational age, stillbirth, COVID-19), and infant outcomes (developmental milestones [motor, cognitive, language, social-emotional, and mental health skills], height, weight, failure to thrive, medical conditions during the first 12 months of life, COVID-19) among pregnant women exposed to single (homologous) or mixed (heterologous) COVID-19 vaccine brand series from 30 days prior to the first day of the last menstrual period to end of pregnancy and their offspring relative to a matched reference group who

	received no COVID-19 vaccines during pregnancy
COVID-19-Associated Hospitalization Surveillance Network (COVID-NET)	The COVID-19-Associated Hospitalization Surveillance Network (COVID-NET) collects data on hospitalized pregnant women with laboratory-confirmed SARS-CoV-2, the virus that causes COVID-19; to date, such data have been limited
COVID-19-Related Obstetric and Neonatal Outcome Study (CRONOS)	COVID-19 Related Obstetric and Neonatal Outcome Study (CRONOS) is an ongoing prospective multicenter registry study for SARS-CoV-2 positive pregnant women, initiated on 3 April 2020 by the German Society of Perinatal Medicine
Delivery Decision Initiative	The Delivery Decisions Initiative is a project from the Ariadne labs, conducting research and social impact work, focused on transforming childbirth care around the world so that every person can start or grow their family with dignity. They develop and implement efforts aimed at improving equitable maternal health care via collaborations with health systems and communities, designing systems that are capable of producing safe, supportive and empowering care for every birthing person everywhere
EthOSS	This is an obstetric surveillance system collecting data from Ethiopia. It is a partner of INOSS
EUROCAT	European system for aggregating information from registries gathering data on congenital anomalies and pregnancy outcomes (livebirths, stillbirths and terminations of pregnancy), updated twice a years
German Obstetric SurveillanceSystem (GerOSS)	GerOSS (German Obstetric Surveillance System) aims at generating deeper insight into relevant risk factors to improve diagnosis and treatment of severe complications during pregnancy and delivery. As such it is primarily conceived as a system for quality improvement and less as a register. Another focus is the provision of an information and communication platform for dissemination of these insights. Finally, incidences of selected rare obstetric events may be derived
Global Network Maternal Newborn Health Registry (GN-MNHR) (includingCOVID study)	This is an active maternal and neonatal data collection system with multiple LMIC sites. A prospective, population-based registry that startedin 2008; it enrolls and follows up on pregnant women and their newborns up to 42 days postpartum. A sub-study to the Maternal Newborn Health Registry will be conducted to understand the prevalence of COVID-19 among pregnant women, the association between COVID-19 and pregnancy outcomes, and the Knowledge, Attitudes, and Practices of pregnant women related to COVID-19 and its prevention during pregnancy. Women who consent to participation in the MNHR COVID sub-study will provide a blood specimen at or near delivery to be tested for COVID-19 antibodies. Four Global Network sites (Guatemala, Bangladesh, Nagpur India and Pakistan) will also collect and analyze blood specimen from participants during antenatal care visits
Global Network Maternal NewbornHealth	The Global Network for Women's and Children's Health Research (Global Network) is a partnership dedicated to improving maternal and child health outcomes and building health research capacity in resource-poor settings by testing cost-effective, sustainable interventions that provide guidance for the practice of evidence-based medicine. This unique collaboration includes 8 multidisciplinary research sites and a Data Coordinating Center. Scientific oversight for the Global Network comes from the Eunice Kennedy Shriver National Institute of Child Health and Human Development, which is part of the National Institutes of Health within the U.S. Department of Health and Human Services
Global Pregnancy Collaboration (CoLab)	The goal of the Global Pregnancy Collaboration (CoLab) is to improve the health of mothers and their infants by facilitating harmonized perinatal data management and collaborative research. This is accomplished by developing standardized generic data dictionaries that cover the needs of all maternal child health care—from the simplest in the most resource poor countries to the most sophisticated research in moreprivileged areas

Global vaccine data network	The GVDN addresses limitations in vaccine safety. They aim to work with vaccine safety and effectiveness experts, global heal th agencies, and other global non profit health alliances to help assure the safety and risk benefit of vaccines through vaccine monitoring b y evaluating vaccine safety concerns through analysis and evaluation of large clinical databases, evaluating vaccine effectiveness to faci lit ate risk/benefit analyses, leading a coordinated response to concerns regarding vaccines, such as vaccine hesitancy, and seeking out a nd securing funding for collaboration on vaccine safety monitoring projects.
Grupo Castrillo- Spanish NeonatalNetwork	Grupo Castrillo is a Spanish network for neonatal infections surveillance. Since 1995 the network is collecting prospective data about neonatal sepsis and antimicrobial resistance, viral infections, congenital infections, and other related topics (infectious biomarkers, central catheter complications, etc.)
Helping Mothers Survive and Helping Babies Survive	Jhpiego participates in a consortium of global partners to provide and promote these training programs that provide evidence-based learningmodules designed to improve and sustain the skills of midwives, nurses, doctors, and those who provide direct care during pregnancy, labor and birth.
India/Maathri	Maternal and perinatal Health Research collaboration, India (MaatHRI) is a UK India collaboration for maternal and perinatal health research established in September 2018. MaatHRI means 'mother' in Sanskrit. Currently, MaatHRI includes sixteen hospitals across six states in India. It is a partner to the INOSS network.
Interagency working group onreproductive health in crises	IAWG is an international coalition of organizations and individuals working collectively to advance sexual and reproductive health and rights in humanitarian settings
INTERCOVID study	This is the next phase of the INTERGROWTH 21ST project. It is a study aimed to develop new "prescriptive" standards describing normal fetal growth, preterm growth and newborn nutritional status in eight geographically diverse populations, and to relate these standards to neonatalhealth risk (INTERBIO 21ST)
International Clearinghouse for BirthDefects Surveillance and Research	The organization brings together birth defect surveillance and research programmes from around the world with the aim of investigating andpreventing birth defects and lessening the impact of their consequences
International Network for Evaluation of Outcomes of Neonates	iNeo maintains a standardized neonatal intensive care unit (NICU) database and provides a unique opportunity for researchers to participate in collaborative projects on a national and international scale. Health care professionals, health services researchers and health administrators participate actively in clinical and epidemiological outcomes, health services, health policy and informatics research aimed at improving the efficacy and efficiency of neonatal care
International Network of ObstetricSurvey Systems (INOSS)	INOSS is a multinational collaboration of organizations conducting prospective population-based studies of serious illnesses in pregnancyand childbirth
ISGlobal Maternal, Child, Reproductive Health Research	The Barcelona Institute for Global Health (ISGlobal) was set up in 2010 as a result of an initiative of the ”la Caixa” Foundation working with academic and government institutions interested in creating a centre of excellence in research and knowledge translation in Barcelona equipped to meet the new challenges facing global health in the 21st century. Our roots, however, go back much further. Today, ISGlobal encompasses over 30 years’ experience in the field of health and is a consolidated hub of excellence in scientific research drawing on expertise from both the hospital environment and academic institutions

Israeli Neonatal Network	The Israel Neonatal Network (INN) is a voluntary consortium of all neonatal departments in Israel. The Israel National Very Low Birth Weight VLBW) Infant Database was established in 1995 under the auspices of the INN. The main objectives of the database are the application of quality data for the assessment of morbidity and mortality trends of VLBW infants; benchmarking of individual neonatal unit performance in comparison to national data; quality of care and management; planning of national, regional and institutional structure and policy development; longitudinal developmental assessment and for collaborative research programs
Italian Obstetric Surveillance System(ITOSS)	The Italian Obstetric Surveillance System (ItOSS) collects and disseminates information on severe maternal morbidity and mortality. Since 2017, the surveillance system of maternal mortality, coordinated by the Istituto Superiore di Sanità (ISS), has been collecting comprehensive and reliable data on maternal mortality in 13 Italian regions (Piedmont, Lombardy, Veneto, Friuli Venezia Giulia, Emilia-Romagna, Marche, Tuscany, Lazio, Campania, Apulia, Calabria, Sicily and Sardinia), accounting for 91% of total births in Italy. Between 2008 and 2016, through the National Centre for Disease Prevention and Control (Centro nazionale per la prevenzione e il controllo delle malattie – CCM), the Ministry of Health consistently funded a series of ISS-coordinated multiregional projects which allowed further development and consolidation of the surveillance
JHU International Center for Maternaland Newborn Health	This interdisciplinary team applies expertise in public health, behavioral sciences, nutrition, medicine, engineering, and informatics. They rely on workforce development in Sub-Saharan Africa and South Asia to implement and evaluate low-cost solutions to prevent illnesses and deaths in the world's most vulnerable mothers and babies
Korean Neonatal Network (KNN)	A neonatal surveillance network in Korea
Le Comité national d'experts sur la mortalité maternelle (CNEMM)	The National Committee of Experts on Maternal Mortality (CNEMM) was created in 1995 by order of the Ministry of Health with the mission ofexamining maternal deaths documented by a confidential investigation, identifying the factors involved in the occurrence of these deaths and to propose preventive measures. This mission involves a specific information collection system, the National Confidential Survey on Maternal Mortality (ENCMM), whose scientific coordination is ensured by the National Institute of Health and Medical Research (Inserm) (unit 1153 , EPOPé team)
Magee Obstetric Maternal and Infant(MOMI) Database and Biobank	MOMI Database and Biobank collects obstetric biological materials along with annotated clinical information via a rigorous process for qualitycontrol. Our unique, web-based inventory system tracks our biological specimens, linking them to annotated clinical data behind a secure, HIPAA compliant server
Malawi Maternal Health and Safe Motherhood Initiative	This is a maternity waiting village in malawi, with support from UNC Global Women's health. They have several ongoing studies, several focusing on HIV
Maternal health and Covid-19(MA-CoV) Study	Ma-CoV is a study aimed to characterize the clinical presentation of COVID-19 in pregnancy, evaluate the incidence of infection during pregnancy, identify risk factors of maternal and neonatal morbidity and mortality associated with SARS-CoV-2 infection as well as the risk of mother-to-child transmission of SARS-CoV-2
Maternal health task force	The Maternal Health Task Force (MHTF) at the Harvard Chan School of Public Health strives to create a strong, well-informed and collaborative community of individuals focused on ending preventable maternal mortality and morbidity worldwide. The vision for MHTF is that it serves as a space that not only identifies and shares promising research, but serves as a catalyst for research improvement and innovation

Maternal, Newborn & Child HealthWorking Group (MNCH-WG)	THis is an active maternal and neonatal data collection system. INDEPTH is a network of independent Health and Demographic Surveillance System (HDSS) sites that carry out longitudinal research. The INDEPTH Network Maternal, Newborn & Child Health Working Group (MNCH-WG)coordinate the surveillance of pregnancies and outcome tracking
Maternal-fetal medicine units (MFMU) network at UPMC Magee-Womens Hospital	NICHD established the MFMU Network in 1986 to respond to the need for well-designed clinical trials in maternal-fetal medicine and obstetrics, particularly with respect to preterm birth. The aims of the network are to reduce maternal, fetal, and infant morbidity related to preterm birth, fetal growth abnormalities, and maternal complications and to provide the rationale for evidence-based, cost-effective obstetric practice
MATIMMUNE Study	The main objective of this study is to investigate the impact of timing of vaccination during pregnancy on humoral immune responses in pregnant women at several timepoints during and after pregnancy
Medical Birth Registry of Norway	All maternity units in Norway must notify births to the MBRN. The notification form includes the name and personal identity number of the child and parents, as well as information about maternal health before and during pregnancy, and any complications during pregnancy or birth. This includes information about medicine use in pregnancy, labour interventions, birth complications, maternal complications after birth, whether the baby is born alive, any diagnoses in the child or evidence of congenital abnormalities
MNCH Morbidity and MortalitySurveillance - HaSET	A prospective longitudinal cohort study of pregnant women and children less than two years of age with an aim of understanding the epidemiology of maternal and childhood illnesses and deaths in selected Kebeles of Angolela Tera, Kewet and Shewarobit Woredas in North Shewa Zone, Amhara Region, Ethiopia.
Momentum Maternal and Perinatal Death Surveillance and Review (MPDSR)	MOMENTUM Country and Global Leadership, the World Health Organization, UNFPA, and UNICEF have developed an integrated Maternal andPerinatal Death Surveillance and Response (MPDSR) Capacity Building Package that can be used to support country capacity for MPDSR through virtual means. Capacity building materials for both maternal and perinatal mortality surveillance have been combined into one package, which also includes updated guidance and COVID-19 modules
MotherToBaby	MotherToBaby Pregnancy Studies provide information on medication and vaccine safety in pregnancy. Studies are observational; people who are pregnant are not asked to take any medications or change their current treatments. They follow people who are pregnant who have – andwho have not – taken a medication of interest until they deliver their baby, and then follow their babies for a period of time after birth. They collect information along the way that allows determination of whether the medication/vaccine may pose a risk to a pregnancy or a developing baby
MPD-4-QED (Nigeria)	This program was initiated in Nigeria in 2019 across 54 tertiary level public and private referral level health facilities. It was established to implement a standardized electronic platform for the collection and collation of maternal and perinatal data, to enable routine healthcare data analysis and maternal and perinatal death audits. It will facilitate reporting and feedback at the local, state, regional, and national levels for the improvements in clinical care performance. Currently in its third year with >200,000 participants enrolled.
Multi-Omics for Mothers and Infants(MOMI) Biorepository Platform	This platform builds off an existing pregnancy biobank in the Sylhet district of Bangladesh, known as AMANHI-Bangladesh. The AMANHI-Bangladesh biobank contains biological samples from mothers and infants and related clinical and epidemiological data. Researchers use the sample and data collected by the biobank to identify biological and genetic markers that may predict a mother's increased risk of adverse outcomes including preeclampsia, preterm birth, and small for gestational age (smaller or less developed than normal for the baby's sex and gestational age). Through the MOMI Biorepository Platform grant, researchers will maintain the existing biobank infrastructure and develop a

	scale-up plan that will include other biobank sites and partners. Researchers also aim to identify new insights and biomarkers for preterm birth and other pregnancy complications that will help to inform predictors and treatment options. The MOMI Biorepository Platform will alsoinclude capacity-building components for research staff and data scientists at the Bangladesh field site
National Neonatal ResearchDatabase (NNRD)	The NNRD is a national resource holding real-world clinical data captured in the course of care on all admissions to NHS neonatal units in England, Wales, Scotland and the Isle of Man. Neonatal units submit data through their Electronic Patient Record system supplier. At present, there is information on around one million babies and 10 million days of care in the NNRD. The NNRD is available to support audit, evaluations, bench-marking, quality improvement and clinical, epidemiological, health services and policy research to improve patient care and outcomes
National Registry for surveillance and epidemiology of perinatal Covid-19 infections	This National Registry represents a collaboration between the American Academy of Pediatrics Section on Neonatal-Perinatal Medicine, the Vermont-Oxford Network (VON) and MedNAX (an organization of private neonatologist)h
NEOCOSUR network	This network includes 36 public and private tertiary centers, all University-affiliated. They aim to conduct continuous evaluation of mortality and morbidity of very low birth weight infants (VLBWI) population in the region, develop of predictive adjustment tools that allow benchmarking between centers, conduct clinical observational studies with data provided from the DBU, and non-interventional prospective studies, and design/ conduct clinical trials to evaluate the effectiveness of specific therapeutic interventions
Neonatal Research Network Japan	This is the Neonatal research network database in Japan. All infants who were born in the participating hospitals with gestational age less than 32 weeks and with birth weight at or less than 1500g admitted to participating facilities within 28 days after birth are registered in the database. Those infants who were born alive but died in a delivery room are also included. As of January 1, 2021, 131 perinatal centers are participating in the network
NethOSS	This is an obstetric surveillance system collecting data from Netherlands. It is a partner of INOSS
Nordic Obstetrics SurveillanceSystem (NOSS)	This is an obstetric surveillance system collecting data from the Nordic countries
Obstetric-fetal pharmacology researchcenter (OPRC)	The mission of the OPRC Network, formerly the Obstetric-Fetal Pharmaceutical Research Units Network, was to improve the safety and effective use of therapeutic drugs in pregnant and lactating people. The network's overall goal was to promote and facilitate cooperative multidisciplinary research to enhance the understanding of obstetric pharmacokinetics (PK) and pharmacodynamics (PD). OPRCs provided theexpert infrastructure needed to test therapeutic drugs during pregnancy. The centers allowed researchers to conduct safe, technically sophisticated, and complex studies that helped clinicians protect the health of pregnant people, improve birth outcomes, and reduce infant mortality
PAHO Perinatal InformationSystem (SIP)	This is an active maternal and neonatal data collection system. Perinatal Informatic System (SIP) by PAHO is a perinatal clinical record that Ministries of health and maternity services (public and private) have adopted
peri-COVID	The periCOVID study was set up by a group of doctors and researchers who are interested in understanding if pregnant women who test positive for the novel coronavirus (SARS-COV-2) can transmit the infection to their unborn babies and if baby's of mothers who have been vaccinated against SARS-CoV-2 will be protected from COVID-19 infection

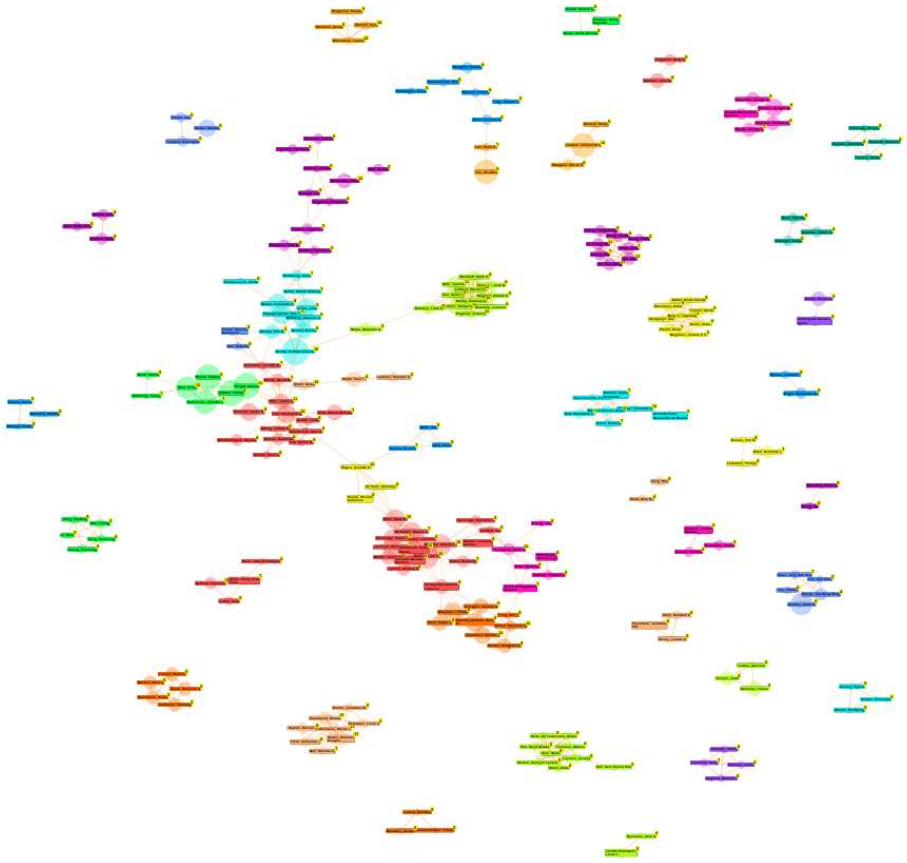
Perinatal Problem IdentificationProgramme	The Perinatal Problem Identification Program (PPIP) is a tool that makes perinatal and maternal death audits easier. It provides simple analysis on monthly deaths, causes of death and avoidable factors
Pregnancy and Neonatal Outcomes inCOVID-19 (PAN-COVID)	PAN-COVID is a global registry of women with suspected COVID-19 or confirmed SARS-CoV-2 infection in pregnancy and their neonates; understanding natural history to guide treatment and prevention. The overall aims of PAN-COVID are to evaluate the association of suspectedCOVID-19 and confirmed SARS-CoV-2 infection in women in pregnancy with: 1. Miscarriage, 2. Fetal growth restriction and stillbirth, 3. Pre- term delivery, 4. Vertical transmission. They collaborate with 13 other national and international COVID-related maternal and neonatal registries
Pregnancy Risk Assessment Monitoring System (PRAMS)	PRAMS, the Pregnancy Risk Assessment Monitoring System, is a surveillance project of the Centers for Disease Control and Prevention (CDC) and health departments. Developed in 1987, PRAMS collects jurisdiction-specific, population-based data on maternal attitudes and experiences before, during, and shortly after pregnancy. PRAMS surveillance currently covers about 81% of all U.S. births
PRiSMA	PRiSMA is a network of sites funded by BMGF collecting anthropometric, sociodemographic, pregnancy, and child health data. They conduct epidemiological studies, but are also developing the capacity to conduct clinical trials in their populations
QoC WHO	The goal of the Quality of Care is to work with the WHO to develop national quality and operational plan to reduce maternal and neonatal mortality. QoC programmes have been set up in Bangladesh, Cote d'Ivoire, Ethiopia, Ghana, India, Kenya, Malawi, Sierrra Leone, Tanzania, Uganda
Registry for pregnant women exposedto SARS-CoV-2 (COVID-19, CONSIGN study)	The COVI-PREG registry aims to collect data to understand the natural history of the SARS-CoV-2 among pregnant women and the impact on maternal, pregnancy and neonatal outcomes. The study objectives are to characterize the clinical course of SARS-CoV-2 infection during pregnancy, assess the risk assessment of vertical transmission and congenital lesions, quantify the risk of adverse maternal outcomes, pregnancy outcomes and neonatal outcomes, and identify additional risk factors and risk modifiers
Reproductive, Maternal, & Child Health (RMNCH)	This is a collaboration of a Nepalese and US-based NGOs, supporting health innovation in Nepal, conducting research and innovation to address evidence, implementation, and policy gaps in the equity, quality and accessibility of healthcare. They have a particular MNCH research division
Reproductive, Maternal, Newborn, Child, and Adolescent Health (RMNCAH)division - Impact of COVID-19 on the Health and Nutrition of Women and Children in Low- and Middle- Income Countries study	A hub for global child health-focused activities and connects researchers and health-care professionals around the world, with focus on RMNCAH; Special interests in scaling up evidence-based, community setting interventions and implementation of reproductive, maternal, newborn, child and adolescent health and nutrition interventions in humanitarian contexts
Safety Platform for EmergencyVaccines (SPEAC)	This effort is funded by CEPI to promote harmonization of safety assessment across research platforms and enable meaningful analysis and interpretation of the safety profile of CEPI vaccines
Sanofi Pasteur PregnancySurveillance Program	The Sanofi Pasteur Pregnancy Registries are an organized, systematic collection of data on pregnant women vaccinated with one or more of the following vaccines: Menactra® (Meningococcal [Groups A, C, Y and W-135] Polysaccharide Diphtheria Toxoid Conjugate Vaccine), Adacel®(Tetanus Toxoid, Reduced Diphtheria Toxoid and Acellular Pertussis Vaccine Adsorbed), Fluzone® Quadrivalent (Influenza Virus Vaccine), MenQuadfi® (Meningococcal [groups A, C, Y, W] conjugate vaccine), Dengvaxia®(Dengue tetravalent vaccine, live, attenuated), Flublok® Quadrivalent (Influenza Virus Vaccine)

SASOG - Covid 19 study	The primary aim of the present study was to describe the char-acteristics and outcomes of hospitalized pregnant women infected with SARS-CoV- 2 in South Africa who were admitted for treatment of clinical SARS-CoV- 2 illness or other indication, in order to inform evidence-basedguidance for pregnant women in South Africa
SET-NET	CDC's Surveillance for Emerging Threats to Mothers and Babies Network (SET-NET) detects the effects of health threats on pregnant people and their babies by collecting data from pregnancy through childhood. It uses evidence-based, actionable information to help save and improve the lives of mothers and babies
Shoklo Malaria Research Unit - Motherand child health team	The mother and child health (MCH) team run a network of antenatal clinics and delivery facilities for the border population and have documented over 70,000 pregnancies and their outcomes. This massive effort has resulted in a phenomenal contribution to the evidence base on the treatment of maternal malaria, the safety of the artemisinin derivatives in pregnancy including in the first trimester and the need to adapt the dosing of antimalarial drugs during gestation
Slovakia Obstetric SurveillanceSystem (SOSS)	Slovak Obstetric Survey System (SOSS) is the working group for active surveillance of severe acute maternal morbidity and maternal mortalityin Slovak Republic (SR). It works closely with the UKOSS
Strengthening Epidemiological Surveillance in Benin and Burkina Fasofor an Effective Response to COVID-19(STREESCO) study	As part of the health systems set up by Benin and Burkina Faso's health authorities, this project develops with intended users, epidemic surveillance and response system that will be effective, sensitive, coordinated, and adapted to a low-resource context. The epidemic surveillance system will produce and process the ongoing information needed to execute early alerts and to control the health system's response
Sub-Saharan Congenital Anomaly Network (sScan)	support for congenital anomaly surveillance and build capacity in Sub-Saharan Africa. The network is being established by a team of investigators with experience in CA surveillance, diagnosis and care of children with CA in Africa, from different countries including; Nigeria, South Africa, Uganda and the United Kingdom
Swedish Medical Birth Register	The Pregnancy Register (www.graviditetsregistret.se) collects data on pregnancy and childbirth, starting at the first visit to antenatal care and ending at the follow-up visit to the antenatal care, which usually occurs at around 8–16 weeks postpartum. The majority of data is collected directly from the electronic medical records. The Register includes demographic, reproductive and maternal health data, as well information on prenatal diagnostics, and pregnancy outcome for the mother and the newborn
Swedish Neonatal Quality Register	SNQ provides data and information to decisionmakers, professionals, families and the public, all in order to stimulate quality improvement, research and development. Maternal, pregnancy and delivery data are automatically extracted from medical records and transferred via the Swedish Pregnancy Register
Swiss Neonatal Network &Follow-up group	The chief aim of the Swiss Neonatal Network & Follow-Up Group (SwissNeoNet) is to maintain and / or improve the quality and safety of medical care for high-risk newborn infants and their families in Switzerland through a coordinated program of research, education and collaborative audit. In support of its aim, SwissNeoNet hosts the official medical quality register for the Swiss level III and level IIB units. Participation for these units is mandatory according to the intercantonal declaration for Highly Specialized Medicine (HSM) of September 22, 2011 and the Society's Standards for Levels of Neonatal Care in Switzerland
Task Force on Research Specific to Pregnant Women and LactatingWomen (PRGLAC)	PRGLAC adviseS the Secretary of Health and Human Services (HHS) regarding gaps in knowledge and research on safe and effective therapies for pregnant women and lactating women

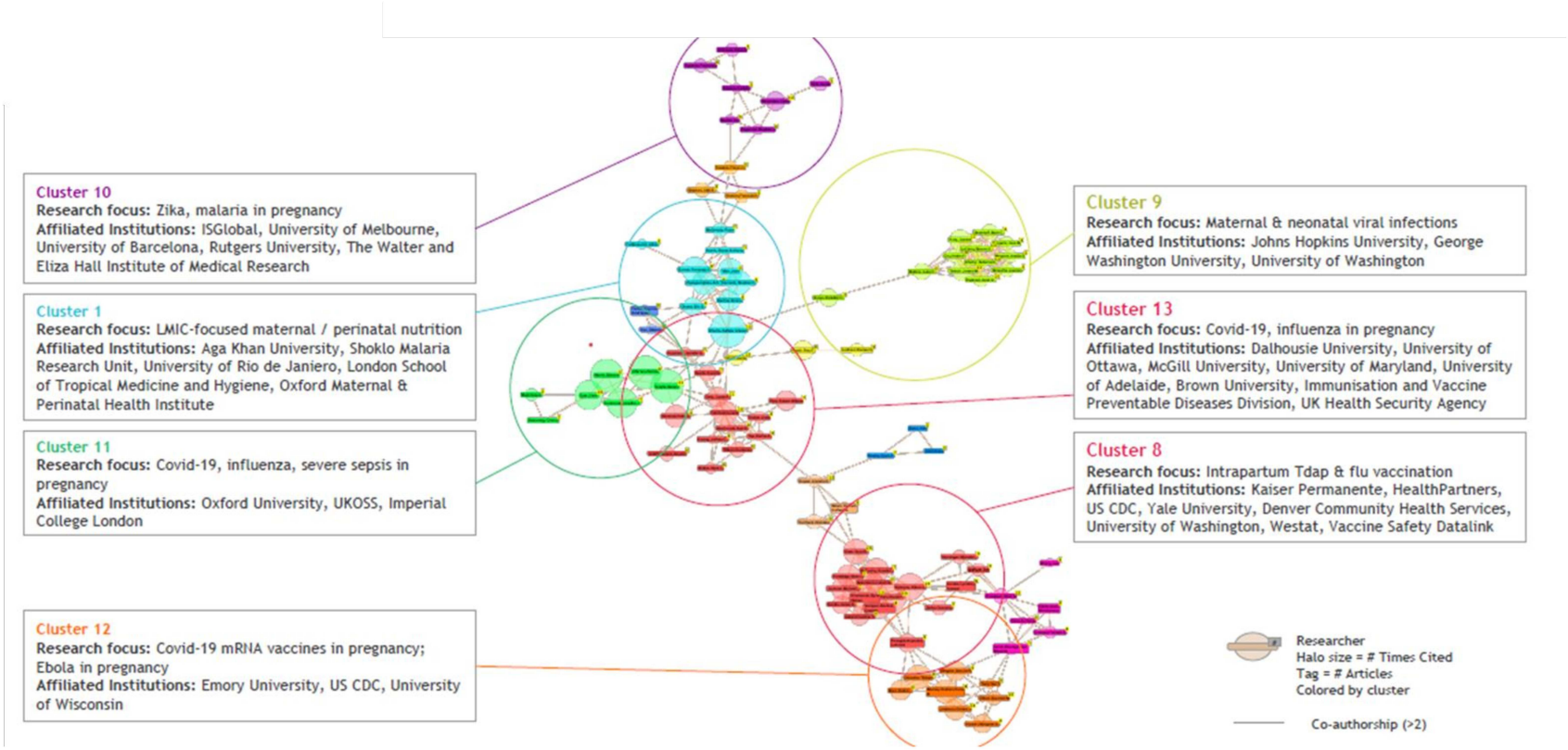
The Irish Centre for Maternal and Child Health Research (INFANT)	This is an initiative based at the University of Cork. INFANT utilizes local and global data to address the international need for research and innovation to improve health outcomes for mothers and babies
The PRECISE Network	The PRECISE Network is a collaboration between 13 research institutions and is hosted at King's College London in the UK, investigating three important complications of pregnancy, hypertension, fetal growth restriction, and stillbirth.
Ubomi Buhle	Ubomi Buhle is a national project aimed at improving our understanding of what exposures during pregnancy, such as medicines, substances and diseases, can result in poor birth outcomes e.g. birth defects, low birth weight, stillbirth, premature birth and neonatal death
UK Neonatal Collaborative	In 2012, the UK Neonatal Collaborative (UKNC), consisting of all NHS neonatal units, formed. These sites contribute data to the NNRD. This database, now includes details of 100,000 infants admitted to neonatal care each year
UK Obstetric SurveillanceSystem (UKOSS)	UK-wide surveillance network of pregnant women aimed to enable cohort, case-control, and epidemiological studies focused onrare disorders
US v-safe pregnancy registry	This is a registry of women who self-identify as pregnant who received COVID-19 vaccination, investigates pregnancy outcomes, pregnancy complications, and problems with the newborn
Vaccine Safety Datalink	The Vaccine Safety Datalink (VSD) is a collaborative project between CDC's Immunization Safety Office and nine health care organizations. The VSD started in 1990 and continues today in order to monitor safety of vaccines and conduct studies about rare and serious adverse eventsfollowing immunization. The VSD uses electronic health data from each participating site. They have a particular focus on maternal populations although their main focus is the general population
Vaccines and Medications in Pregnancy Surveillance System	The Vaccines and Medications in Pregnancy Surveillance System (VAMPSS) is a nationwide post-marketing surveillance system established to comprehensively monitor the use and safety of vaccines and medications during pregnancy
WHO multicountry study(WHO MCS) network	The Network for Improving Quality of Care for Maternal, Newborn and Child Health (Quality of Care Network) is a broad partnership of committed governments, implementation partners and funding agencies working to ensure that every pregnant woman, newborn and the child receives good quality care with equity and dignity. The goals of the Network are to halve maternal and newborn deaths and stillbirthsin health facilities by 2022 and to improve patients' experience of care in participating in health facilities in Network countries
Zero Infections in Pregnancy Honduras	Originally called the Zika in Pregancy in Honduras, this is a prospective pregnancy cohort study in Teguchigalpa, Honduras, collecting sociodemographic, maternal, and perinatal health information
ZIKV IPD-MA	In February 2017, a group of researchers formed the ZIKV Individual Participant Data (IPD) Consortium to conduct an individual participant data meta-analysis (IPD-MA) of ZIKV related longitudinal studies of pregnant women and their children. The research objectives of the ZIKV IPD Consortium IPD-MA are to (1) estimate the absolute and relative risks of miscarriage, fetal loss, and short- and long-term sequelae of fetal Zika exposure for women that experience symptomatic and asymptomatic ZIKV infection during pregnancy; (2) identify and quantify the relative importance of different sources of heterogeneity in the risk of adverse fetal, infant, and child outcomes among infants exposed to ZIKV in utero; and (3) develop and validate a prognostic prediction model [9] to identify high risk pregnancies and inform communication between health care providers and their patients and to optimize mobilization of resources between health care providers and their patients and to optimize mobilization of resources (e.g., vector control strategies, antenatal care,and family planning programs).

Supplementary Figure 1. Results of the Quid analysis

a) Clustering of research efforts



(b) focus on the most connected network



c) Maternal and perinatal health topics identified by Quid analysis