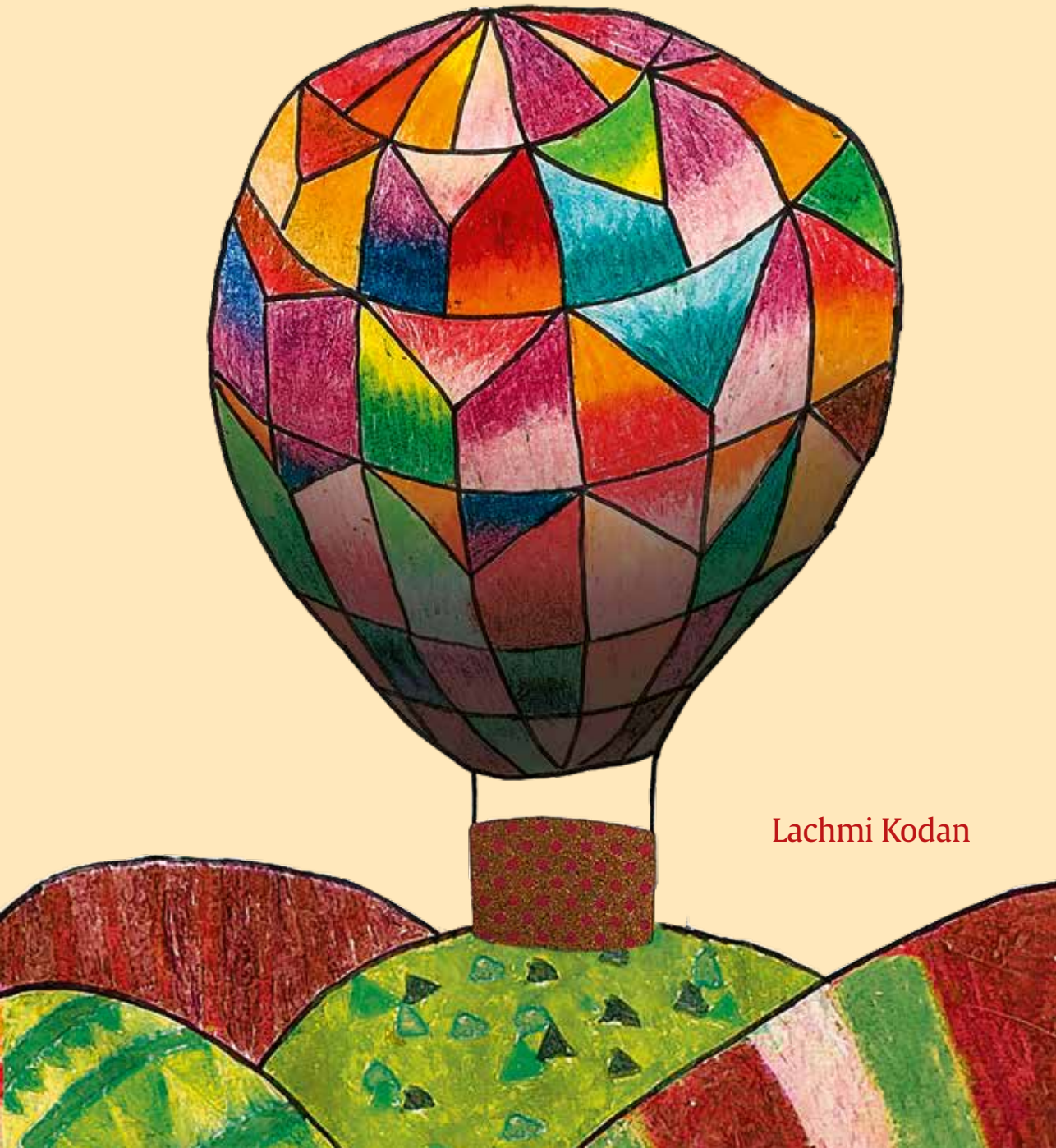
Safe Motherhood

Maternal Mortality in Suriname

Implementation of Maternal Death Surveillance and Response to reduce preventable maternal deaths



Lachmi Kodan

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Lachmi Reshma Kodan

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Maternal Mortality in Suriname: Implementation of Maternal Death Surveillance and Response to reduce preventable maternal deaths
Lachmi Reshma Kodan
Doctoral Dissertation, University of Utrecht, The Netherlands

Maternal Mortality in Suriname

Implementation of Maternal Death Surveillance and Response to reduce preventable maternal death

Maternale Mortaliteit in Suriname:
Implementatie van Maternale Sterfte Surveillance en Response ter reductie van voorkombare moedersterfte
(met een samenvatting in het Nederlands)

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Lachmi Reshma Kodan

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Aan de Surinaamse vrouwen,

Mijn ouders,

Ashirya en Rageesh

Contents

General Introduction

1

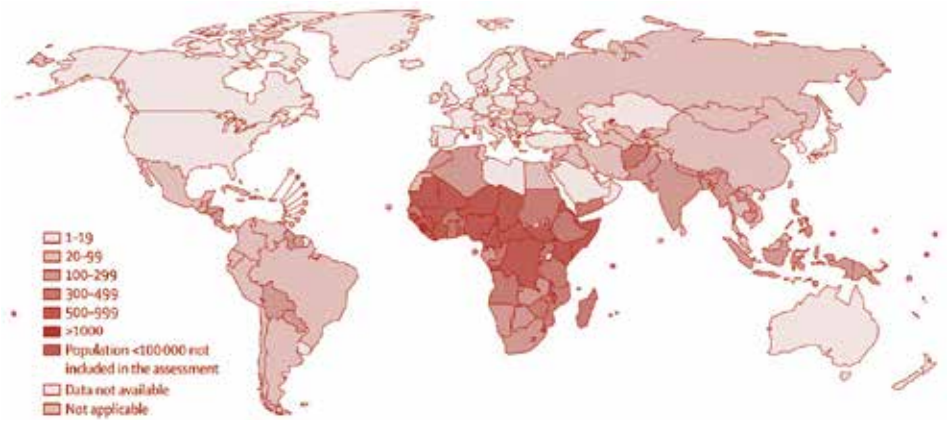
'Mama bee da sipi, a ta tja bunu ku hogi tuu'

(A mother's belly is as a ship, it carries good and bad)

Saramacaans Nongo

In 1987 the Safe Motherhood Initiative called for action to raise awareness for maternal mortality, considered a neglected tragedy.[1,2] Neglected because those who suffered were poor, not influential, and women. Maternal mortality ratio (MMR) in the least developed countries were 200 times higher than in developed countries, one of the highest disparities in public health at that time.[1] A maternal death is the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and the site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management, but not from accidental or incidental causes.[3] MMR is the number of maternal deaths per 100,000 live births.[4] Maternal mortality has been high on the global agenda, and several safe motherhood programs have been developed since the proclamation of the Safe Motherhood Initiative in 1987.[5] The Millennium Development Goals (MDG) and its sequel the Sustainable Development Goals (SDG) set targets to reduce maternal deaths. Nevertheless, maternal mortality is still one of the most prominent global health challenges nowadays. In 2017 an estimated 295,000 women died from causes related to pregnancy, with 99% of these fatalities in low- and middle-income countries (Figure 1).[4]

Figure 1. Worldwide estimated maternal mortality ratios per 100.000 live births



Reference: Alkema L, Chou D, Hogan D, Zhang S, Moller AB, Gemmill A, Fat DM, Boerma T TM. Global, regional, and national levels and trends in maternal mortality between 1990 and 2015, with scenario-based projections to 2030: a systematic analysis by the United Nations Maternal Mortality Estimation Inter-Agency Group. *Lancet*. 2016;387(10017):462-474.

MMR in the least developed countries were 60 times higher than in high-income countries in 2017.[4,6] Therefore, maternal mortality is not merely about the existence of diseases but also concerns socioeconomic determinants of health and human rights.[1,5,7,8] In fact, maternal mortality is a touchstone of inequality and inequity between and within countries and is an indicator of health system performance.[7,9,10]

Maternal death surveillance and response (MDSR)

The SDG call for an integrated approach to health. SDG 3.1 targets an MMR for all countries of fewer than 70 per 100,000 live births.[4] This target is part of the bigger goal to "ensure healthy lives and promote well-being for all at all ages".[4] Strategies are focused on access to quality and, respectful care for women and family planning.[11] This approach is linked to universal health coverage and fundamental human rights.[8,11] The MDSR is part of this holistic approach and was introduced by the WHO in 2012, with the primary goal of eliminating preventable maternal deaths.[7,11] MDSR is a continuous cycle linking health information systems and quality improvement processes from local to national level.[11] The purpose of MDSR is to identify, review, analyse and classify every maternal death, and to identify substandard care factors and gaps in care. The first step in identifying maternal deaths is to assess all deaths in women of reproductive age (RAMoS) that occurred during pregnancy or within 42 days postpartum. Following the identification, a maternal death review (MDR), a qualitative, in-depth investigation of the causes and circumstances of the death is conducted. From the review recommendations can be formulated, followed by responses to the recommendations (actions) and monitoring of these responses (Figure 2).

Three phases of delay and obstetric transition

Preventing maternal mortality not only involves medical issues but also delays in the accessibility of quality care. The three phases of delay are a conceptual framework that identifies obstacles in the access and availability of quality and emergency obstetric care.[5]

Figure 2. Maternal Death Surveillance and Response (MDSR) system: a continuous action cycle

Legend: M&E- Monitoring and Evaluation. Reference: World Health Organization. Maternal Death Surveillance and Response. Technical Guidance. Information for action to prevent maternal death. 2013.

The first phase of delay is a delay in the decision of the woman or her family to seek care. Financial issues, distance, and previous experience with the health care system could influence the decision to seek care. The second phase of delay is the delay in reaching an adequate healthcare facility and depends on distance, finances, costs, availability of transportation and roads, and the distribution of facilities. The third phase of delay concerns the quality of emergency and preventive care in the health facilities.[5,12] The abovementioned delays are associated with the degree of socioeconomic development of a country and explains why different strategies are required for maternal mortality reduction, even within countries.[13] Every country deals with these delays at its own pace. As countries' socioeconomic development improves first and second delay problems decline and more third delay problems emerge.[13]

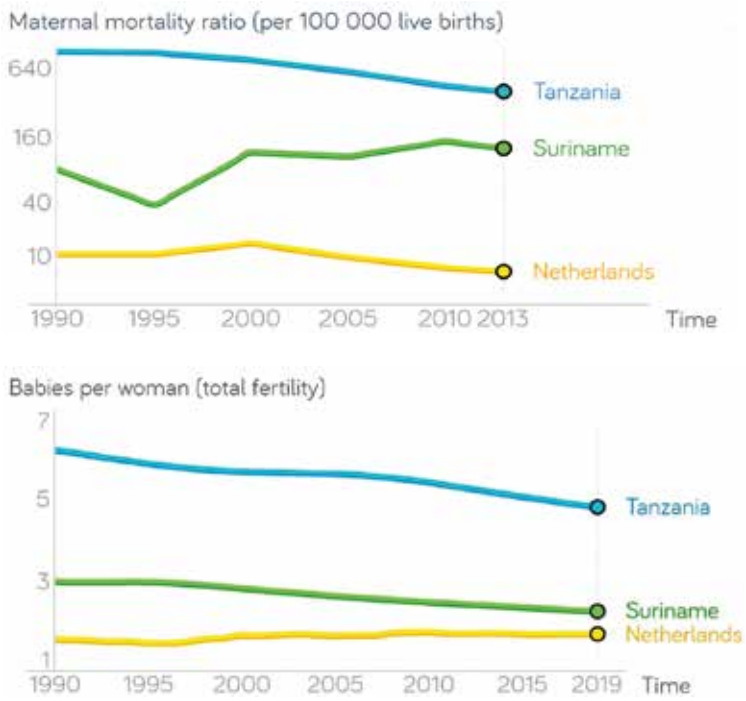
Obstetric transition describes the transition of countries from higher MMR/fertility to lower MMR/fertility.[13] There are five stages of obstetric transition, and each stage requires different approaches for improvement.

- In *stage I* (MMR > 1000 per 100,000 live births), women experience a situation close to natural history, with very little to nothing being done to reduce the risk of maternal mortality. Often political and economic factors impede access and delivery of the most basic services.
- In *stage II* (MMR 999 - 300 per 100,000 live births), a higher proportion of women start seeking care, yet the infrastructure and the health care system are weak. There is a lack of access (first and second delay) and poor quality of care with shortages of staff and resources.

- *Stage III* (MMR 299 - 50 per 100,000 live births and decreasing fertility rates) is considered a tipping point as women generally reach hospitals, and quality of care becomes the determinant of health outcomes (third delay).
- In *Stage IV* (MMR < 50 per 100,000 live births), indirect causes are more important, non-communicable diseases increase, and overmedicalization emerges as a threat to quality care and improved health outcomes.
- *Stage V* (MMR < 5 per 100,000 live births) is the desired stage, with no avoidable maternal deaths.

MMR and fertility rate change over time in low-income, middle income country, and high-income countries as shown in Figure 3.

Figure 3. MMR and fertility rates for Tanzania, Suriname and the Netherlands



Legend

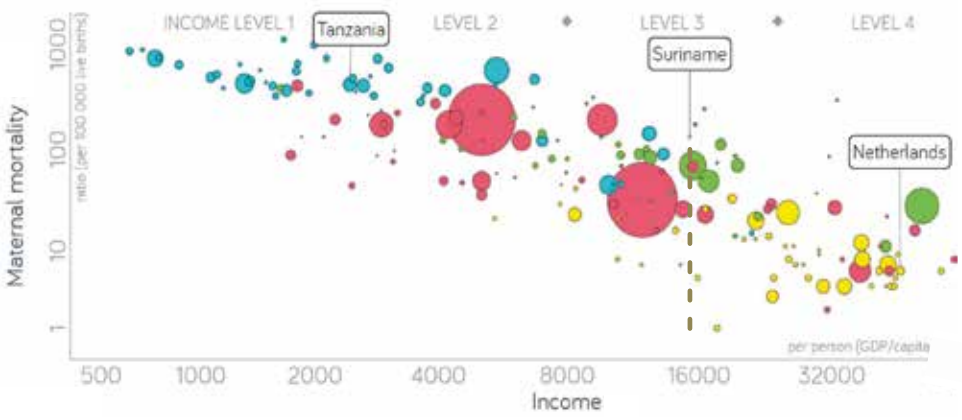
Tanzania: blue, low income and obstetric transition phase II; Suriname: green, middle income and obstetric transition phase III; Netherlands: yellow, high income and obstetric transition phase IV/V; Reference: Gapminder. Available from: www.gapminder.org/tools

The figure illustrates that countries evolve to lower MMR and fertility rates over time as described in the concept of obstetric transition, sometimes after an initial increase or upwards/downward trend. When all 33 countries in the Americas, including USA and Canada were classified according to their obstetric stages from 1990 to 2015, none were in stage I or stage V. Most countries were in stage III, only one country remained in stage II (Haiti) and six moved from stage III to IV.[7]

Maternal mortality and socioeconomic status

The gross domestic product (GDP) provides information regarding the size of a country's economy and how it is performing. It is an indicator of the general health of the economy. In broad terms, an increase in GDP is interpreted as a sign that the economy is doing well.[15] As income levels rise, citizens demand improved quality of life, including improved access affordable high-quality health care. Health care expenditures (HEs) as a percentage of GDP have increased in almost all regions in the world.[16] Maternal mortality seems to be associated with the income level of a country as seen in Figure 4.

Figure 4. Level of income and maternal mortality ratio (MMR), 2013



Legend:

Countries on this line have similar income as Suriname but varying MMR

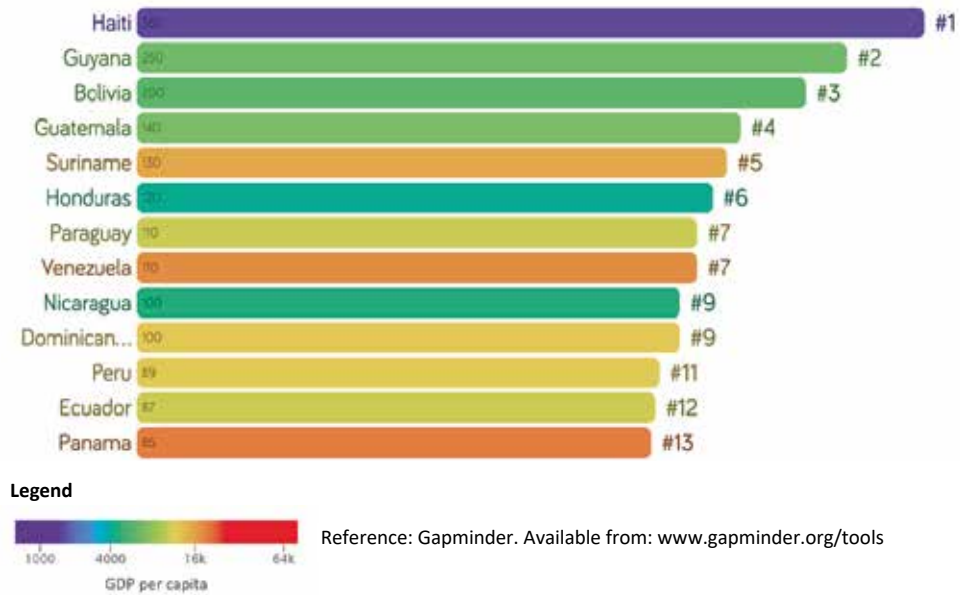
Colors reflect regions of the world, size of bubble reflects population size

Reference: Gapminder. Available from: www.gapminder.org/tools

MMR in low-income countries can be 60 times higher than in high-income countries.[4] However, MMR also differs in countries with similar income. For example, countries with a comparable income to Suriname (MMR 130) have MMR varying between 1 and 240 (Figure 4, dashed line).[17] Differences in MMR in countries with similar economies could be attributed to inequities in the countries.[9,18-20]

Figure 5 depicts the countries in the Americas and Caribbean region with the highest MMRs, with income-levels indicated in distinct colors. Suriname was one of the five countries with the highest MMRs (130 per 100,000 live births) in 2015, despite the higher income level, as compared to many other countries in the region with lower maternal mortality ratios. Although lower MMR may, in part, be due to less rigorous measurements in other countries, Suriname's performance in maternal mortality was unexplained as the country performs well on maternal health indicators as percentage of deliveries by skilled birth attendants and number of antenatal care visits.[21]

Figure 5. Countries with the highest maternal mortality ratio (MMR) in the Americas & Caribbean and their Gross Domestic Product (GDP)



Reference: Gapminder. Available from: www.gapminder.org/tools

Suriname

Socioeconomic characteristics

Suriname is a multi-ethnic, upper-middle income country on the northeast coast of South America. It covers an area of 163,820 km^2, of which 90% consists of tropical rainforest and most of the population (80%) lives in the narrow coastal plain to the north. With an estimated population of 576,000 people, it is one of the least populous countries in the Americas.[22,23] The ethnic distribution in 2018 of the women in Suriname was: Hindustani (28%), Maroon (23%), Creole (17%), Javanese (13%), mixed (12%), Indigenous (4%) and other (3%).[24] The country struggled with several economic challenges in the nineties, but recovered steadily so that, by 2014, the GDP per capita nearly decupled.[23,25] During this period of economic growth, the health care infrastructure improved nationwide.[23] In 2014, legislation regarding basic health care insurance for all was enacted.[26] To address persisting inequities among urban, rural, and interior regions, the Multi-annual Development Plan proposed several large investment projects.[27] However, since 2015 the financial situation of the country has been deteriorating again, and, by 2018 the GDP had almost halved.[25] The impact of the fluctuating economic situation in Suriname on maternal health has yet to be determined.

Health care system

The Ministry of Health is responsible for the health care system in Suriname. There are five major hospitals, four of which are located in Paramaribo and one in the district of Nickerie at the western border. There are smaller hospitals in Marowijne, on the east coast, one in Wanica, a district nearby Paramaribo, and in the interior. The only psychiatric hospital is in Paramaribo. Primary health care facilities include the following:

1. Regional health services (51 primary health clinics) in the coastal area
2. Private primary health care clinics (approximately 200) in the coastal area
3. Medical Mission (54 primary health clinics) in the rural interior

The Bureau of Public Health (known as the BOG, its Dutch acronym) is responsible for the public health programs.

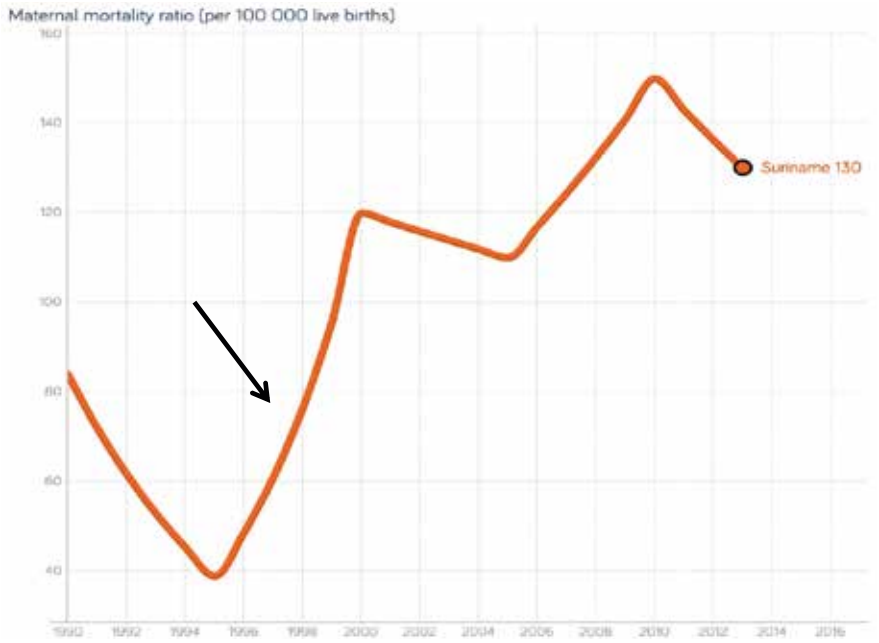
Maternal health

There are an estimated 10,000 live births per annum in Suriname, of which 92% occur in health care facilities (86% in hospitals and 6% in primary health care centers), 4% at home, and 4% at unknown locations. In 2018, 85% received antenatal care at least once, and 98% of pregnant women gave birth with the assistance of a skilled birth attendant, of which 97% were midwives.[24] Providing universal access to health care for mothers and their newborns remains a challenge, and disparities in access are often related to geographic location and insurance coverage. The Safe Motherhood and Newborn Health Action Plan, developed in 2014, emphasised the lack of uniformity in protocols (ante-, intra-, and postpartum and emergency obstetric care), which limited the monitoring of the quality of services.[28]

Vital statistics and maternal mortality

The Central Bureau of Civil Affairs (CBB) registers all deaths and 98% of all live births in Suriname. BOG is responsible for vital registry and uses data from the death certificates. A confidential enquiry into maternal deaths in Suriname between 1991 and 1993 reported a maternal mortality ratio (MMR) of 226 per 100.000 live births (six times higher than vital registry).[29,30] In 2000, BOG initiated active surveillance of maternal deaths by a monthly enquiry into maternal deaths in all hospital obstetric units to address underreporting. Figure 6 demonstrates how, due to improved surveillance of maternal mortality in Suriname, it seemed as if there was an increase in MMR since 2000, as highlighted with the yellow arrow.[20] Despite the active surveillance, there were several gaps in the surveillance system resulting in less reliable MMR figures and misidentification: 1) no screening and analysis of all deceased women of reproductive age were performed, especially on those who had died in non-obstetric wards; 2) the cause of death was determined by the attending physicians without (multidisciplinary) case review or classification; 3) every death in pregnancy, including coincidental and accidental, was counted as a maternal death.

Figure 6. MMR in Suriname according to vital statistics, 1990 to 2013



Reference: Gapminder. Available from: www.gapminder.org/tools

Thesis Objectives

General objectives

The general objective is to reduce preventable maternal deaths by establishing MDSR in Suriname. We hypothesised that implementing and improving the complete MDSR cycle in Suriname could reduce maternal mortality.

Specific objectives

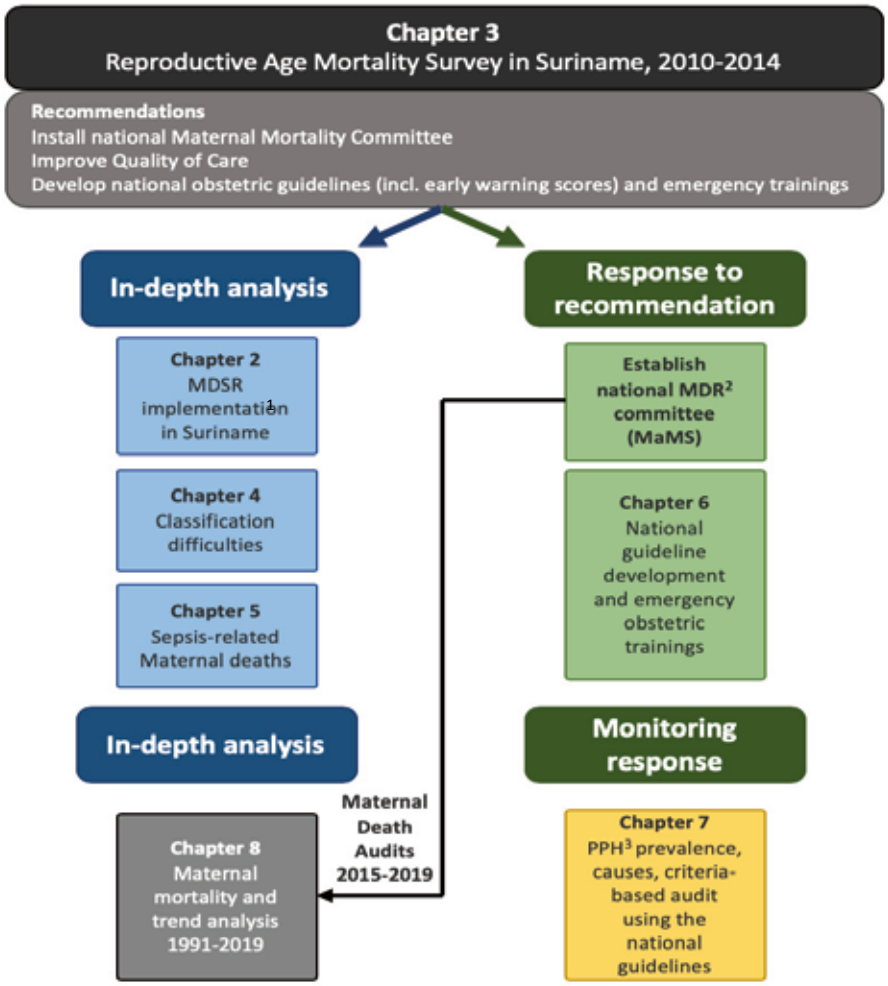
1. To improve the identification of maternal deaths by performing a reproductive age mortality survey (RAMoS) for the period from 2010 - 2014 and develop a framework for improved reporting of maternal mortality.
2. To analyse the extent of maternal mortality in Suriname, determine the underlying causes and substandard care factors, and to provide recommendations for maternal death reduction.
3. To do an in-depth analysis of the most frequent underlying causes of maternal deaths (sepsis and postpartum haemorrhage [PPH]), aimed at identifying specific gaps in care.
4. To explore challenges that exist in the attribution of underlying causes and subsequent classification of maternal deaths despite using the WHO International Classification of Diseases - Maternal Mortality (ICD-MM) guidelines.
5. To review all maternal deaths in Suriname systematically by a national maternal death review committee, which is one of the recommendations of the 2010 - 2014 RAMoS.
6. To develop national guidelines on PPH and hypertensive disorders in pregnancy, and conduct obstetric emergency care training, which is another recommendation of the 2010 - 2014 RAMoS.
7. To monitor the use of and adherence to one of the national guidelines by performing a criteria-based audit on the management of PPH.

Outline of this thesis

In the general introduction (**Chapter 1**) the concept of MDSR, delay in care, obstetric transition, and the influence of socioeconomic determinants on maternal mortality are described. In addition, background information on the socioeconomic situation and health system in Suriname is provided. In **Chapter 2** an overview is provided of the history of maternal mortality registration and surveillance in Suriname. Furthermore, the current status of MDSR implementation and the steps required to fulfil the MDSR cycle are described. **Chapter 3** forms the basis of this thesis, and presents the study, describing the analyses of the maternal deaths in Suriname between 2010 and 2014, and the deducted recommendations. In **Chapter 4** the difficulties in the classification of the pregnancy-related deaths in Suriname between 2010 and 2014 were analysed. The MDR committees of Suriname, Jamaica (a middle-income country), and the Netherlands (a high-income country) applied the WHO ICD-MM guidelines and compared the maternal death classification. In **Chapter 5** an in-depth analysis was conducted of all sepsis-related maternal deaths (the most frequent underlying cause) in Suriname between 2010 and 2014. In **Chapter 6** the response to one of the recommendations of the 2010-2014 study, namely the development of relevant national guidelines and obstetric emergency training, was described. In **Chapter 7** the monitoring of one of the responses (PPH national guideline development) was evaluated by performing a criteria-based audit to evaluate PPH management utilizing the national guidelines. In **Chapter 8** five years (2015 - 2019) of systematic maternal death review by the national maternal mortality review (MaMS, Dutch acronym) committee was assessed. This committee was instituted as a response to another recommendation of the 2010-2014 study (Chapter 3). Moreover, a trend analysis of maternal deaths in Suriname was performed by comparing this study (2015 – 2019) with the one of 2010 - 2014 (this thesis) and the one in the study period 1991 – 1993.[29]

Chapter 9 and **10** provide the general discussion and summary.

Figure 7. Overview of the outline of this thesis: Establishing Maternal Death Surveillance and Response in Suriname



Legend

[1] MDSR: Maternal Death Surveillance and Response; [2] MDR: Maternal Death Review; [3] PPH: postpartum haemorrhage

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From passive surveillance to response: Suriname's efforts to implement Maternal Death Surveillance and Response (MDSR)

2

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BACKGROUND

The reduction of maternal deaths was the focus of Millennium Development Goal 5 in 2000 and remained a priority in the Sustainable Development Goals established in 2015.[1-3] It is essential to identify underlying causes and contributing factors to gain more insight into the gaps in care next to solely counting maternal deaths to prevent avoidable deaths.[4] A maternal death review is a medical audit with an in-depth qualitative investigation of the causes and circumstances of death.[5] By performing audits, an attempt is made to understand the "how and why" of the death, analyze substandard care, and formulate "lessons learned" to initiate steps for improvement. Combining audits with national guideline development, training, and monitoring of implementation could improve guidelines adherence.[6,7] The different types of medical audits are verbal autopsy (at community level), clinical audit (at facility level, by involved healthcare workers), and confidential enquiry (at national level, by an independent committee).[5]

A Maternal Death Surveillance and Response (MDSR) cycle is a continuous action cycle that provides information on maternal mortality surveillance and audit and on the actions needed to improve care and avert avoidable maternal deaths.[5,8] The WHO introduced the MDSR approach in 2012 to establish accurate data collection and translate “lessons learned” to action plans and national policies, followed by monitoring to capture the effects.[9] In Latin America and the Caribbean (LAC), MDSR was implemented in 2015 in six countries: Brazil, El Salvador, Columbia, Jamaica, Mexico, and Peru, which serve as an example for other countries.[10]

Although the maternal mortality ratio (MMR) declined with time from 226 per 100,000 live births in 1991-1993 to 154 per 100.000 live births in 2010, Suriname was designated by the Pan American Health Organization (PAHO) as one of the ten priority countries in LAC for reduction of maternal mortality in 2010.[11-13] Several intentions existed to improve surveillance and classification in Suriname for years, but integrated maternal deaths reviews were not performed until the installation of a national maternal mortality review (MaMS, Dutch acronym) Committee in 2015. This article aims to describe the MDSR implementation in Suriname and its facilitators and barriers. We share the "lessons learned", as experienced by the

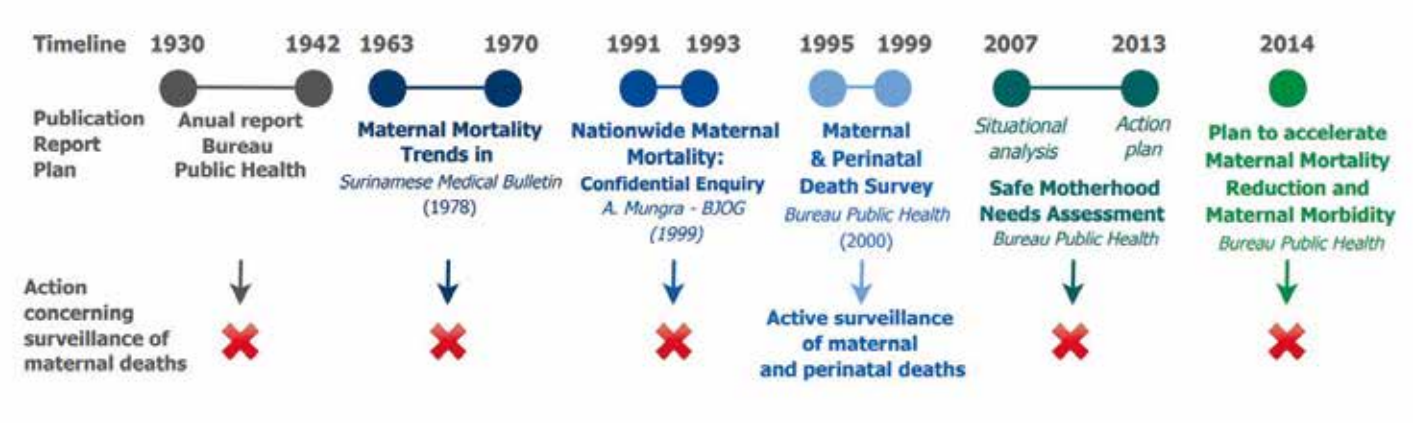
health care providers and public health experts involved in MDSR implementation. This MDSR process is described in three time slots: 1) pre-2015, MDSR and safe motherhood initiatives before the installation of Committee MaMS; 2) 2015 – 2019, during the MDSR implementation process; 3) 2020 and beyond, the way forward to fulfil the MDSR cycle.

Maternal death surveillance and safe motherhood initiatives before 2015 in Suriname

Suriname is a middle income country in South America with 583.200 inhabitants.[14] There is an average of 10.000 deliveries in a year, of which 86% in the five major hospitals, 6% in primary care, 4% at home and 4% at an unknown location.[15] The Ministry of Health (MOH) coordinates the health care systems in Suriname. The Bureau of Public Health (BOG, Dutch acronym) is responsible for public health programs and manages the surveillance and analysis of health data. Although every hospital is collecting data on maternal health key indicators, no comprehensive national health information system exists.[16]

The registration of deaths in Suriname goes back to the 19th century. At the time the death of inhabitants was registered only if they were not enslaved.[17] An official civil registration system is in place in Suriname since 1917 and vital events, including births and deaths of all inhabitants, are registered.[18] The Central Bureau of Civil Affairs (CBB, Dutch acronym) is responsible for civil registration. Notification of death is obliged by law and must occur within 24 hours in the capital and within seven days in the districts.[19] Death notification is through a death certificate consisting of an 'A-form' with personal information, and a 'C-form' with medical information about the cause and circumstances of the death filled in by the medical doctor. The Bureau of Public Health (BOG) registers the C-form.[20] However, in practice, the C-form is often completed a long time after the burial.[12] In 2000 BOG received 85% of the of C-forms, which is higher than the 58% in 1995.[21]

Figure 1. Overview of local plans of action on maternal mortality in Suriname until 2015



The first confidential enquiry into maternal mortality in Suriname was conducted in 1991-1993 and reported that 53% of the maternal deaths were not certified - in contrast with the 15% non-certification of the general deaths.[22] The problems with C-forms lead to underreporting or late reporting of maternal deaths.

Figure 1 presents a timeline of the initiatives carried out to improve maternal health care in Suriname. Specific reports on maternal deaths were published by vital registry (BOG) in the annual reports of 1930-1942 for the first time. Subsequently, in 1978, the MMR of 1963-1970 was reported in a publication in the Surinamese Medical bulletin.[23] These reports did not provide information on the identification procedure of maternal deaths.[23] Maternal death reviews in Suriname were performed for the first time in 1991-1993 as part of a confidential enquiry conducted by Mungra et al.[13] This study highlighted substantial underreporting (63%, n=41/63) and entailed several recommendations:[22,23]

1) use various methods and sources to improve maternal death surveillance, such as Reproductive Age Mortality Surveys (RAMoS) and active case detection instead of only the C-forms (i.e., capture and recapture), and
2) perform maternal death audits to identify substandard care factors and provide recommendations.[13]

Following these recommendations and a maternal death underreporting of 31% in a 1995-1999 BOG survey, BOG initiated active maternal death surveillance in 2000 through a monthly enquiry for deaths in all hospital obstetric units.[21] The attending physician was responsible for the cause of death attribution and no multidisciplinary review or classification of these deaths was performed. As a consequence of the lack of classification, every death in pregnancy, including coincidental and accidental, was counted as a maternal death by vital registration.[12] In addition, this surveillance method did not capture maternal deaths in non-obstetric wards.

To reduce the maternal and perinatal mortality, the MOH performed a situation analysis in 2007: safe motherhood needs assessment.[25] This analysis concluded several gaps in the surveillance system and recommended to:

1) create more awareness about the definition of maternal deaths, so that accidental and incidental deaths are excluded when determining MMR;
2) add information to the C-form about (recent) pregnancy/delivery when a woman of childbearing age dies;
3) create a central notification point for possible maternal deaths;
4) make confidential enquiry mandatory and introduce maternal and perinatal death audit for a continued process of identification, analysis, and action to improve maternal care and prevent avoidable deaths.

Following the situation analysis in 2007, the National Safe Motherhood and Newborn Health Action Plan commenced in 2013 and was evaluated in 2017.[26,27] In 2014, Suriname's progress in the regional "Plan to Accelerate Maternal Mortality Reduction and Serious Maternal Morbidity" was published.[28,29] The abovementioned reports demonstrated the same gaps assessed in 2007 and the 1991-1993 confidential enquiry.[25,30] There was little awareness of safe motherhood and regional plans among health care providers and other stakeholders and they were not involved in the implementation of these plans.[27,28] Besides, due to a lack of capacity, communication and scarce coordination mechanism for the monitoring of actions, implementation was most likely not as successful as intended. [27,28] Surveillance barely improved since the previous scaling up of surveillance (active case detection in hospitals) in 2000. Maternal death audits were not yet part of the existing surveillance system mid-2015.[12,21]

MDSR implementation status of Suriname between 2015 and 2019

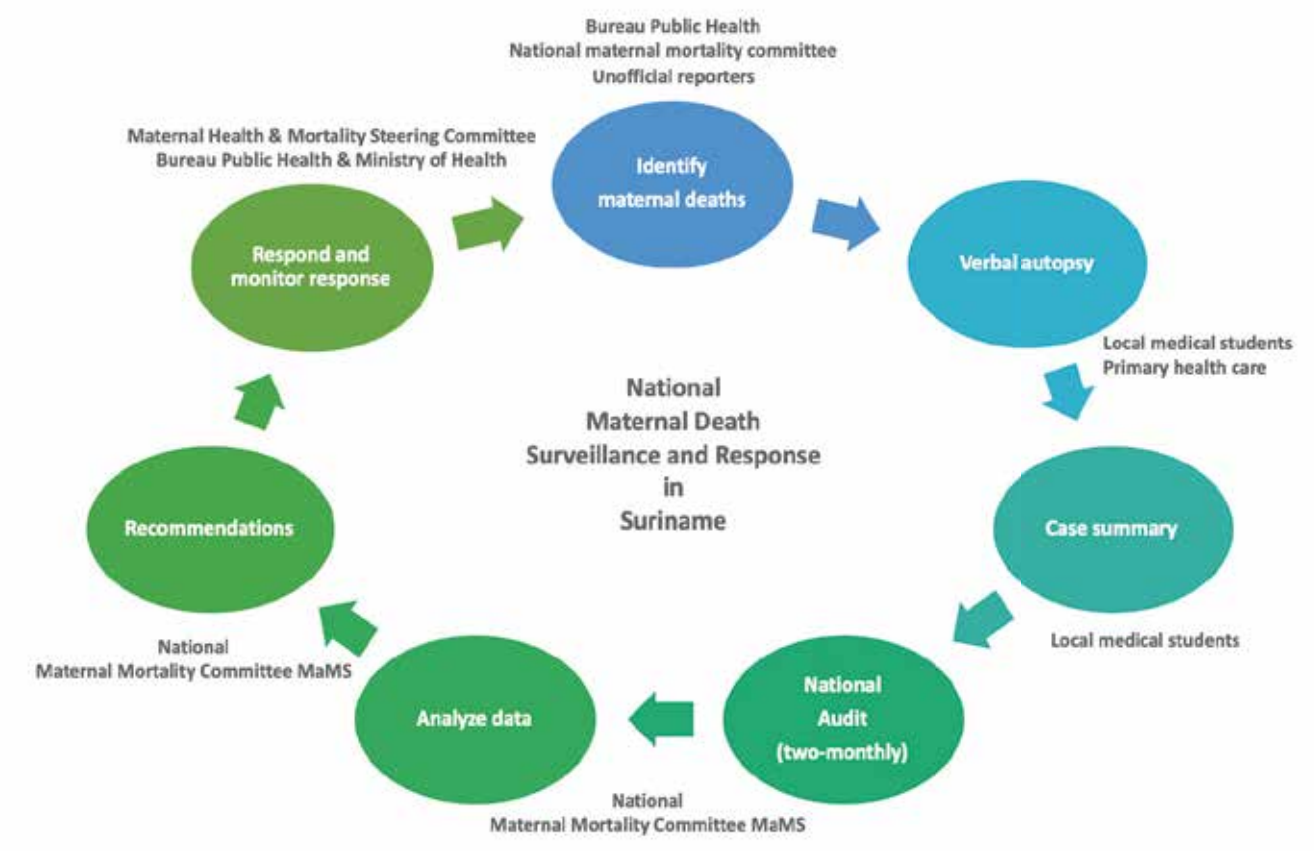
In 2015, a Reproductive Age Mortality Survey (RAMoS) was performed by health care providers to retrospectively identify and audit all maternal deaths between 2010 and 2014.[12] Various methods were used to identify pregnancy-related deaths, as described in previous publications.[12,13,24] Different medical experts determined the death causes and analyzed substandard care. Recommendations were to: (1) Improve maternal death surveillance, (2) install a maternal mortality review committee to audit every pregnancy-related death, (3) implement national guidelines, early warning scores, and (4) improve postnatal care strategies.

Response to a recommendation - Installation of a national maternal mortality review committee:

To ascertain that recommendations would be pursued, the study investigators of the 2010-2014 RAMoS sought collaboration with the MOH, BOG, PAHO, midwifery, and gynecology/obstetric organizations. Consequently, a maternal mortality review committee (MaMS, Dutch acronym) was established in November 2015.[31] Committee MaMs members gather (bi)monthly and audit every pregnancy-related death in the nation. The committee consists of four gynecologists/obstetricians, one midwife, one internal medicine specialist, one BOG representative, two medical students, and several external consultants.[31] Most members are consultants from four of the five major hospitals in Suriname where most of the births take place; primary health care is not represented. Figure 2 depicts the activities currently conducted by the committee MaMS in the MDSR cycle:

1) Active case detection by various sources: (in)formal notification, notification by BOG (C-forms or active surveillance).
2) Sharing of cases (exchange of data) with BOG and vice versa; however, this is not performed regularly yet.
3) Composition of a case summary.
4) Collecting additional case information if necessary, e.g., laboratory results, interview with the health care provider.
5) Verbal autopsy with family members if this may contribute to gain more insight into the circumstances of the death.
6) Maternal death review/audit, classification using the International Classification of Diseases for Maternal Mortality (ICD-MM), and substandard care analysis according to the three-delay model.[32]
7) Dissemination of recommendations with relevant institutions and the MOH and BOG, however, this is not yet consistently done.

Figure 2. MDSR in Suriname in 2020, adapted from the WHO [10]



Some hospitals perform a facility-based review of maternal deaths and report to the committee MaMS. All audits are conducted, guaranteeing the "no blame, no shame" culture.[5,33] Committee MaMS ensures that no litigation of healthcare workers is initiated. Unfortunately, maternal deaths are still not structurally identified and depend on informal notification of health care workers, family, or news sites. Death certificates do not have a pregnancy box, and notification is not obliged.[12] Active surveillance of all deceased women of reproductive age are not yet completely incorporated in BOG's surveillance. Medical students are responsible for a part of the surveillance, data acquisition, case presentation at the audit, and summarise the analysis and recommendations. Figure 3 summarises the facilitators and barriers experienced by committee MaMS in the completion of the MDSR cycle. Sustainable MDSR is still not accomplished since routine surveillance methods are not further improved, facility-based reviews are incidentally performed, no established institution exists responsible for the general coordination and the members of the committee MaMS work voluntarily.

Figure 3. Suriname's facilitators and barriers in installation of MDR committee

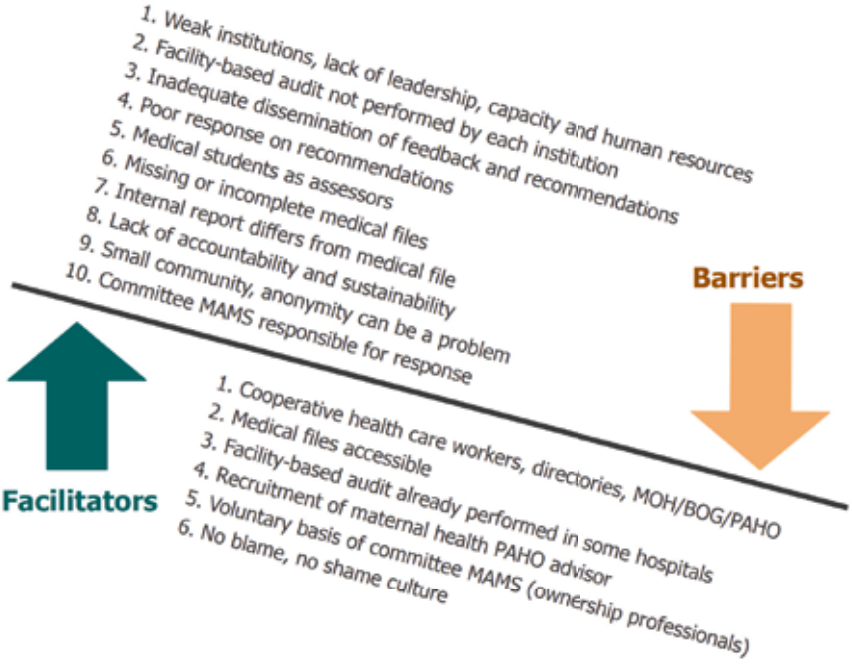
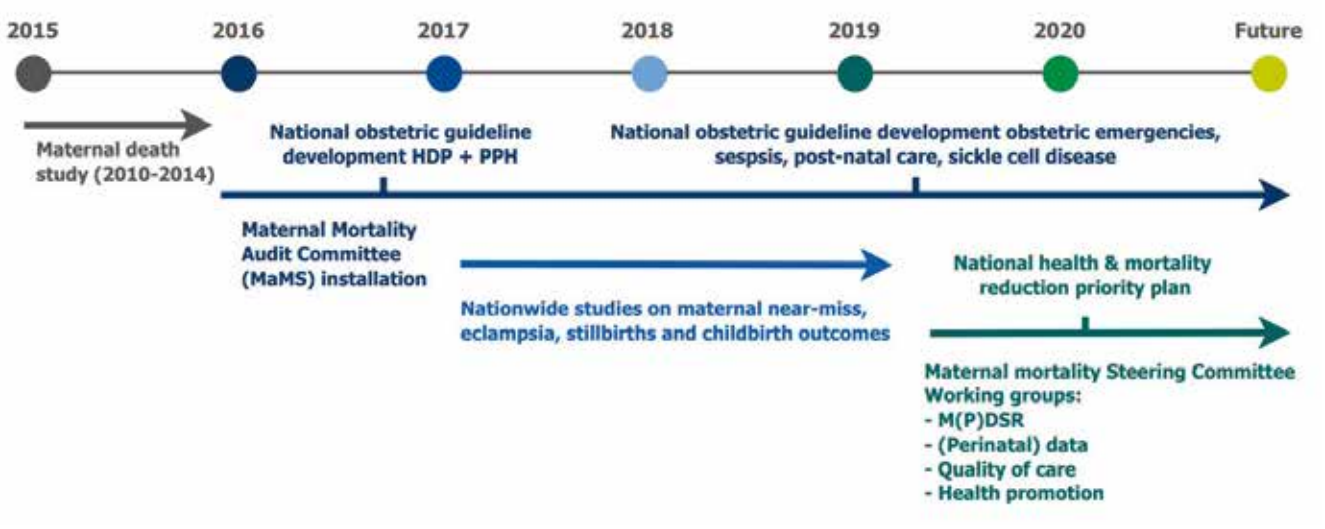


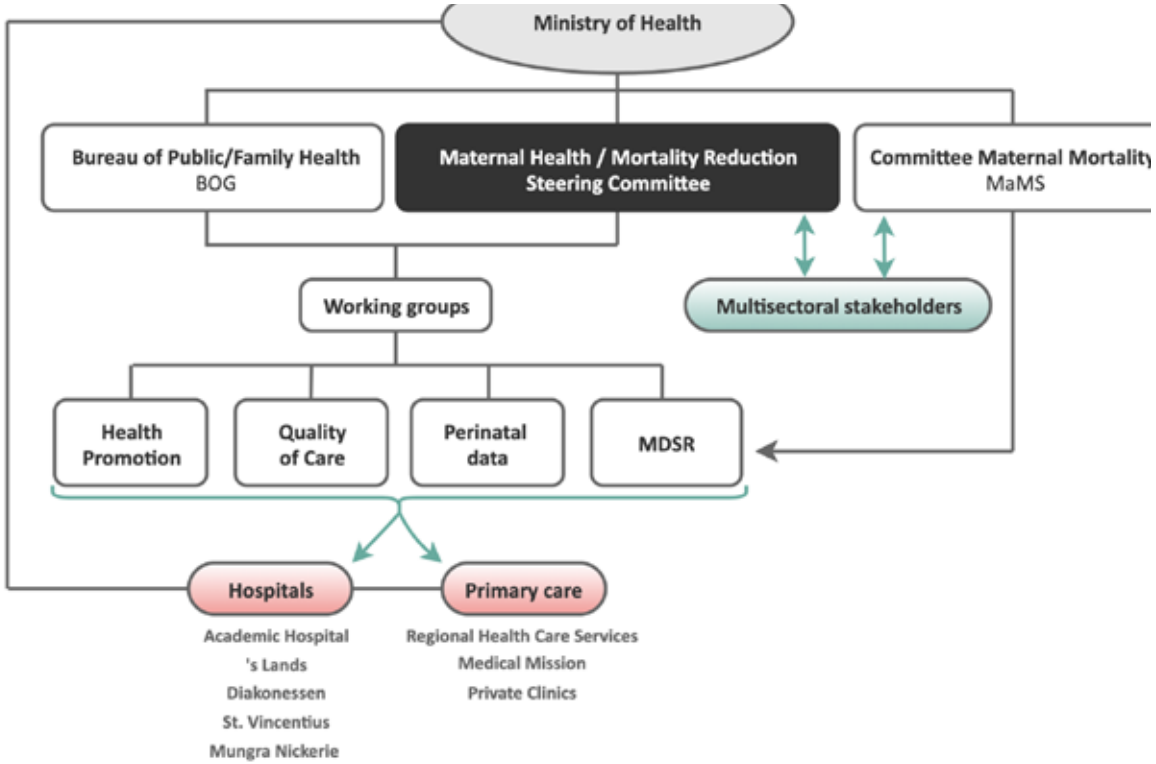
Figure 4. Timeline of maternal health initiatives in Suriname, 2015 to present



Legend

HDP: hypertensive disorders of pregnancy, MaMS: Maternal Mortality Suriname, M(P)DSR: maternal (& perinatal) death surveillance and response, PPH: postpartum haemorrhage

Figure 5. Flowchart of organization of maternal health in Suriname, adapted from the National Maternal Health and Mortality Reduction Priority Plan[3]



Response to another recommendation – guideline development

One of the recommendations on quality of care improvement of the 2010-2014 RAMoS was responded on by the committee MAMS in 2016 (Figure 4). This response included the "bottom-up" guideline development of the most important causes of maternal deaths, namely postpartum haemorrhage (PPH), hypertensive disorders of pregnancy (HDP) and obstetric emergency training.[34] Non-Pneumatic Anti Shock garments (used in hypovolemic shock in case of severe haemorrhage) were provided by PAHO, followed by training in 2018 and 2019 to reduce and treat PPH.[11] Subsequently, the evaluation of the previous guidelines and the development of guidelines on postnatal and antenatal care, sepsis, sickle cell anaemia, emergency obstetrics, and early warning scores followed in April 2019. Facility-based obstetric emergency training was guided by BOG, PAHO and the recently installed maternal health quality of care committee, to enhance guideline implementation and adherence as advised in earlier studies.[6,7] In addition to the quality of care improvement projects, committee MaMS was involved in conducting nationwide studies on maternal morbidity and near-miss (2017-2019), childbirth outcomes, and stillbirths.[16,35]

Next steps toward fulfilling the MDSR cycle in Suriname

Similar to Suriname, other countries in the region have not made great progress in the reduction of maternal deaths.[3,36] Subsequently, the PAHO and its Latin American Centre of Perinatology women and reproductive health (CLAP) called for awareness-raising and accountability.[36]

MOH/BOG and PAHO presented an advocacy paper in April 2020 to call for a multisectoral effort to reduce maternal deaths.[37] They also created an organogram to reinforce the coordination of the maternal health program in Suriname. This organogram includes a national steering committee for maternal health and mortality reduction, overseeing the following working groups (Figure 5):

1. MDSR working group: responsible for improving *surveillance* and maternal death audit, dissemination of *recommendations* and delineation of roles for *response* by specifying specific tasks and responsibilities.

2. Quality of Care working group: responsible for the development and monitoring of national standards of care, update and validate national guidelines facility-based and support national training.
3. Perinatal (data) working group: responsible for introducing, collecting, synchronizing, and analyzing data on perinatal health in Suriname.
4. Health Promotion working group: responsible for the development of a health promotion plan, execute recommendations following maternal death reviews, maternal health education, family planning, and contraception in the communities.

Table 1. Summary of the implementation status of Maternal Death Surveillance and Response (MDSR) in 2020

Already established	To be established
Installation of national Maternal health/mortality reduction steering committee	Official installation of the committee MAMS and the four working groups for maternal health, reinforce the health promotion and perinatal data working group[1]
Coordination framework and terms of references	MDSR focal points supervising facility-based audits
Institutional MDSR focal points designated and trained in surveillance and active case detection	MDSR focal points reinforce performing verbal autopsies
Quality of care working group operational	Specialised assessors for facility audit preparation (nurses, doctors) and external audits (BOG)
	Timely dissemination of recommendations
	Monitoring and evaluation

Legend

[1] Perinatal data working group was installed, but only sporadically active

Table 2. Summary of specific recommendations needed to strengthen Maternal Death Surveillance and Response (MDSR) in Suriname

Legislation
Ensure no disciplinary / litigation measures
Notification of maternal death within 24 hours[1]
Include pregnancy checkbox in death certificate[2]
Timely completion of death certificate
Oblige autopsy for maternal deaths of unknown cause
Finances and human resources
Empower BOG by capacity strengthening
Support committee MaMS (administrative personnel, logistics)
Capacity building institutional MDSR focal points
Include MDSR in preservice training curricula
Involve healthcare workers and create awareness (bottom-up approach)
Involve and educate the community
Funding
Enabling policies
Ensure structural facility-based review
Install special secretariat for MDSR at BOG/MOH
Enable communication and dissemination of findings and recommendations

Legend

[1] Institutions and funeral agencies were recently requested to report maternal deaths within 24 hours;

[2] As a temporary solution, a pregnancy checkbox slip is attached to the "C-form".

This steering committee was installed by the MOH in February 2020, and guides, advises, and closely monitors planned interventions of the working groups and reinforces accountability and multisectoral coordination. MOH has identified multisectoral focal points in non-health ministries and institutions and currently prepares the national Maternal and Neonatal Health Strategy (2021-2025) and Operational Plan (2021-2023).

Strategies to institutionalise MDSR in Suriname

To guarantee sustainable surveillance and improve *identification and notification* of maternal deaths MDSR focal points (midwives/doctors) in each institution (the five hospitals, Medical Mission, and Regional Health Services) are designated. The MDSR focal point in a hospital is responsible for active case detection by monthly

medical file investigation of deceased women of reproductive age. The primary care MDSR focal point assesses community deaths. The MOH issued instructions on the procedure of early reporting and active case detection to health facilities and burial agencies. In addition, the PAHO/CLAP organised training in active case detection, verbal autopsy and review to improve MDSR. Following the identification of a possible maternal death, BOG must be notified via a hotline number, and the case must be entered in an anonymised password protected online database. Also, zero maternal deaths must be reported. The focal point is responsible for the coordination of the facility-based review and reports to BOG and committee MAMS. An external case assessment by specialised trained nurses or medical doctors of BOG will be performed with the assistance of committee MAMS. The monthly audits to determine underlying causes and classification on the national level by committee MaMS should continue. Committee MAMS formulates the recommendations and disseminates them to the relevant institutions and the MOH/BOG. The latter is responsible for an adequate response on the recommendations, evaluation and monitoring, in order to judge the impact on maternal death reduction. In table 1, an overview is given of the implementation status of abovementioned strategies in 2020.

Recommendations to strengthen MDSR in Suriname

In table 2 we summarise the recommendations following the "lessons learned" since the implementation of MDSR in Suriname in 2015. Critical steps in fulfilling the complete MDSR cycle in Suriname (action and response) are the delineation of roles and responsibilities for action, establishment of accountability mechanisms for results, and influencing those in a position to act. The fulfillment of this cycle is challenged by a lack of financial and human resources, leadership, legislation, and inadequate government enabling policies.

MDSR in the future - adding perinatal deaths to the cycle

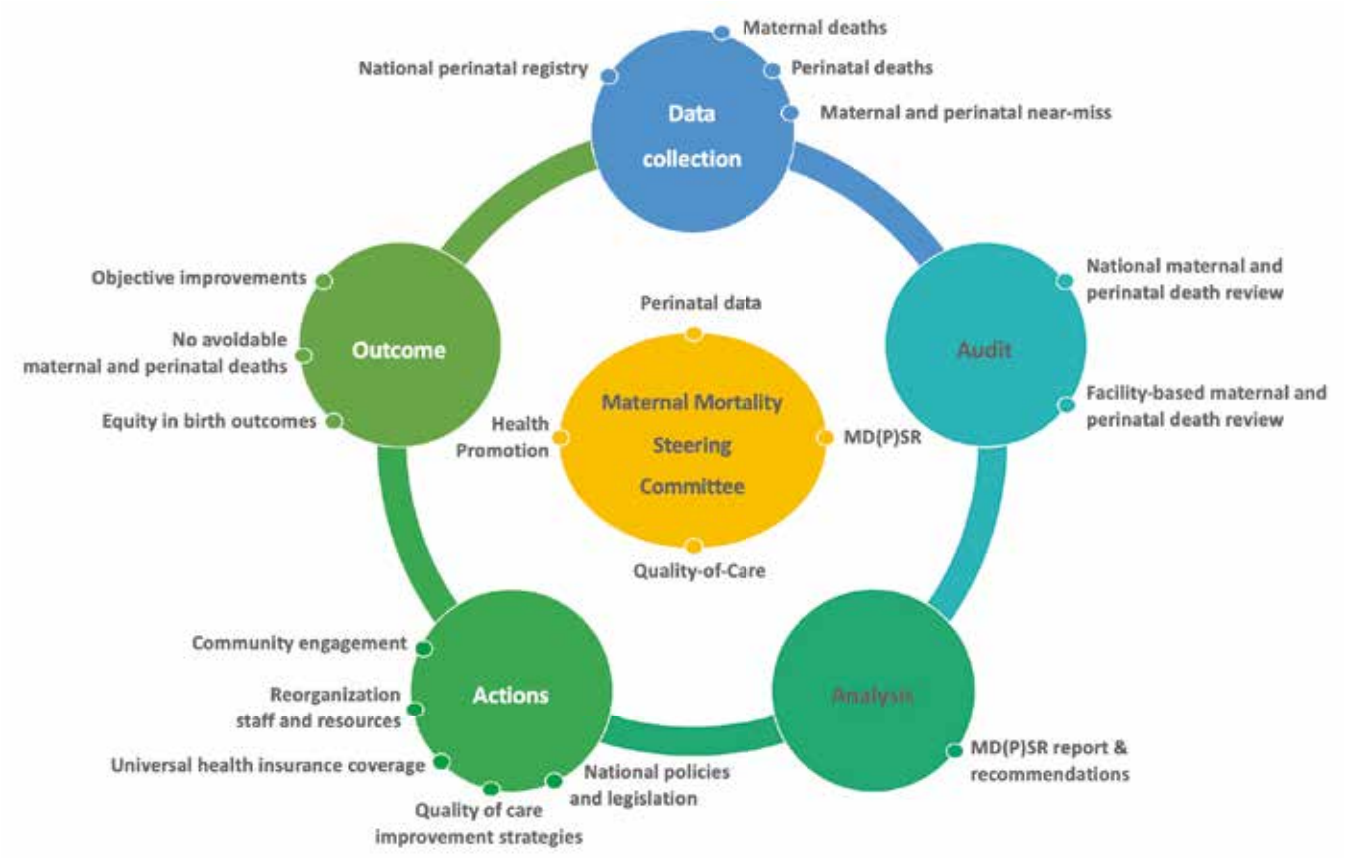
The following steps after the institutionalization of MDSR implementation will be the inclusion of perinatal deaths to the cycle, the Maternal and Perinatal Death

Surveillance and Response (MPDSR) (Figure 6). Maternal conditions often influence perinatal outcomes.[38,39] Additionally, gathering perinatal data and perform perinatal mortality audits in the future, extend the MDSR cycle, linking maternal and perinatal care. Besides focusing on maternal and perinatal deaths, maternal morbidity and near-miss data gathering and audit will be another essential step.

CONCLUSIONS

For decades, several attempts by the MOH alone were insufficient to institutionalise maternal death audits. Structural national maternal death review in Suriname was introduced after a timely and complicated process. Stakeholders' involvement, ownership and leadership were essential to step up in the MDSR cycle from insufficient surveillance to structural audits in 2015. These first steps created a base where the institutions in charge can build on to ensure sustainability. Therefore, a strongly committed government, enabling clear policies and laws to improve MDSR is crucial. In summary, the key elements for successful MDSR implementation are Commitment, "no blame, no shame" Culture, Collaboration, Coordination, and Communication (5 Cs).

Figure 6. The ideal paradigm of the maternal and perinatal death surveillance and response (MDPSR) cycle for Suriname



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Maternal mortality audit in Suriname between 2010 and 2014, a reproductive age mortality survey

3

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ABSTRACT

Background: The fifth Millennium Development Goal (MDG-5) aimed to improve maternal health, targeting a maternal mortality ratio (MMR) reduction of 75% between 1990 and 2015. The objective of this study was to identify all maternal deaths in Suriname, determine the extent of underreporting, audit the maternal deaths and assess underlying causes and substandard care factors.

Methods: A reproductive age mortality survey was conducted in Suriname (South American upper-middle income country) between 2010 and 2014 to identify all maternal deaths in the country. MMR was compared to vital statistics and a previous confidential enquiry from 1991 to 1993 with a MMR 226. A maternal mortality committee audited the maternal deaths and identified underlying causes and substandard care factors.

Results: In the study period 65 maternal deaths were identified in 50,051 live births, indicating a MMR of 130 per 100. 000 live births and implicating a 42% reduction of maternal deaths in the past 25 years. Vital registration indicated a MMR of 96, which marks underreporting of 26%. Maternal deaths mostly occurred in the urban hospitals (84%) and the causes were classified as direct (63%), indirect (32%) or unspecified (5%). Major underlying causes were obstetric and non-obstetric sepsis (27%) and haemorrhage (20%). Substandard care factors (95%) were mostly health professional related (80%) due to delay in diagnosis (59%), delay or wrong treatment (78%) or inadequate monitoring (59%). Substandard care factors most likely led to death in 47% of the cases.

Conclusion: Despite the reduction in maternal mortality, Suriname did not reach MDG-5 in 2015. Steps to reach the Sustainable Development Goal in 2030 (MMR ≤ 70 per 100.000 live births) and eliminate preventable deaths include improving data surveillance, installing a maternal death review committee, and implementing national guidelines for prevention and management of major complications of pregnancy, childbirth and puerperium.

BACKGROUND

Reducing maternal mortality is one of the major challenges to health systems worldwide. United Nations' (UN) Millennium Development Goal 5 (MDG-5) called for a 75% reduction of the maternal mortality ratio (MMR) between 1990 and 2015.[1] The global MMR fell from 385 deaths per 100.000 live births in 1990 to 216 in 2015, corresponding to a decline of 44%.[1]

A vision of ending all preventable maternal deaths has emerged in 2015, being one of the Sustainable Development Goals (SDGs); it aims to reduce the global MMR to less than 70 deaths per 100.000 live births by 2030. Achievement of this target will require robust information systems with high-quality data, specifically on causes of death, as it is of great importance in informing decision-makers and ultimately reducing maternal mortality.[1]

UN's Maternal Mortality Estimation Inter-Agency Group reports that Suriname is one of the few countries with an increase in MMR from 127 in 1990 to 155 in 2015.[2,3] However, a confidential enquiry by Mungra et al. reported an MMR of 226 per 100.000 live births in 1991-1993, suggesting a 31% decrease instead of the 25% increase as suggested by the UN.[4,5] However, it is unclear whether, and if so, to what extent, vital registration has become more reliable over the years.

Maternal health outcomes are strongly associated with higher capital levels, suggesting that an increase in Gross National Income (GNI) per capita should correspond with a reduction in maternal mortality.[6] Suriname was upgraded from lower-middle income country to upper-middle income country in 2013 as the GNI in- creased from $1430 in 1990 to $9370 in 2013.[7] Yet, progress made on different basic health indicators (e.g. under five mortality, health insurance coverage and maternal mortality) in the country is relatively marginal.[8]

According to WHO-estimates, Suriname (MMR 155) belongs to the four worst performing countries in Latin America and the Caribbean (Haiti - MMR 359, Guyana - MMR 229 and Bolivia - MMR 206).[1-3] These are, in contrast to Suriname, low and lower-middle income countries. Suriname's poor performance concerning

maternal mortality is unexplained, as the country performs fairly well on maternal health indicators, e.g. skilled professionals attended 96% of the deliveries in the coastal area and 77% in the rural interior and antenatal care visits occurred at least once in 91% of the pregnant women and at least four times in 67%.[8]

Therefore, the aim of the study is first to identify all maternal deaths in Suriname from 2010 to 2014, second to determine whether maternal deaths were accurately registered and classified, third to assess the reduction of maternal deaths in 25 years, fourth to perform an in-depth audit of the deaths and finally to determine the level of substandard care.

METHODS

Study design: A reproductive age mortality survey (RAMoS) was conducted, using different methods to identify maternal deaths nationwide in Suriname between January 1st 2010 and December 31st 2014.

Study setting: Suriname is a multi-ethnical South American country with a population of 541,638 served by four referral hospitals in the capital, Paramaribo, and one hospital near the western coast, Nickerie. In addition to general practitioners, Regional Health Services (RGD) and Medical Mission (MZ) are responsible for primary healthcare. RGD comprises of 43 facilities serving the whole coastal area and the Medical Mission has 56 health posts throughout the interior. Figure 1 demonstrates the urban area I (Paramaribo) and II (Nickerie), rural coastal area III and rural interior IV. Annually approximately 10,000 live births take place, of which hospitals cover an estimated 82% and primary health institutions 10%, 4% of deliveries are at home and the remaining 4% is unknown.[9] Social insurance, which is for the near poor and poor population, covers an estimated 45% of the general population. The ethnic distribution among the female population is Hindustani (28%), Maroon (24%), Creole (18%), Javanese (14%), Mixed (14%) and other (2%).[10]

Classification & definitions: According to the ICD-MM a pregnancy-related death is the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the cause.[11] A maternal death is the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes. Direct obstetric deaths are those resulting from obstetric complications, while indirect obstetric deaths are those resulting from either a previous existing disease or a disease that developed during pregnancy and which is not due to direct obstetric causes, but which is aggravated by physiologic effects of pregnancy. In unspecified maternal deaths the underlying cause is unknown or cannot be determined. Late maternal deaths are direct or indirect deaths, more than 42 days, but less than 1 year after termination of pregnancy. MMR is the number of direct, indirect and unspecified maternal deaths per 100,000 live births.[11,12]

Figure 1. Map of Suriname: urban (I-II), rural coastal (III) and rural interior (IV)

Data collection: Vital registration Maternal deaths in Suriname are identified mainly by the collection of death certificates and sporadic informing in the hospitals. No independent surveillance systems are adapted to investigate deaths in women of reproductive age. Notification of death is compulsory by law. However, burial can take place with- out the official death certificate, when there is 'an act of death' (an unofficial note signed by a medical doctor). The death certificate is filled in afterwards and often received with a delay (>3 months) and in 15% not received at all. In addition the death certificate lacks a pregnancy checkbox.[13] Identified maternal deaths are not reviewed and thus not classified. Due to a lack of classification, most accidental/incidental deaths and late maternal deaths are also included in the official maternal mortality statistics.

Reproductive age mortality survey (RAMoS): The RAMoS consisted of different steps. First, case records of maternal deaths from 2010 to 2014 identified by vital registration were collected. Second, all medical records of deceased women aged 10 to 50 years in our study period were collected from the archives of all hospitals and the primary health care institutions (Medical Mission and Regional Health Services). Third, The Central Bureau of Civil Affairs provided a list of all deceased women in the country between 2010 and 2014 with an offspring in the pre- ceding year. Fourth, an inventory was performed in the largest mortuary (receiving also deaths occurring outside health care institutions). Fifth, obstetric health care professionals in all facilities were asked their knowledge on local maternal deaths in the past 5 years. Medical records were collected and examined extensively and in case of an incomplete file involved health care professionals were interviewed. Verbal autopsy with family member(s) was performed when maternal deaths occurred outside of the hospital. This was conducted according to the WHO-instrument on verbal autopsy.[14] All available information was gathered (i.e. laboratory and pathology reports, in delivery-books and autopsy information). An elaborate clinical case summary of every pregnancy- related death was made according to the FIGO-LOGIC MDR: Clinical summary form tool.[15] Information on patients, health care providers and hospitals was kept strictly confidential. An

expert committee, consisting of different obstetricians, an internal medicine specialist or anaesthesiologist and midwives, audited all pregnancy-related deaths with two authors (LK and KV) presenting and moderating the sessions. When no consensus was achieved, external ex- pert opinion (JR and HK) was sought. The committee reviewed the cases and agreed to a mode of death, under- lying cause, contributing factors and classified each death using WHO guidelines on applications of ICD-MM.[12] Substandard care factors were analysed according to an adapted version of the FIGO-LOGIC MDR Grid analysis of clinical case management form.[15] Due to lack of guidelines substandard care was defined as a deviation from 'standard practice' according to local clinicians.

Data analysis: Data were manually entered into IBM SPSS version 21.0 (Armonk, New York, USA) for analysis. All maternal deaths were individually analysed and cross-linked with registered maternal deaths by civil registration. Causes, contributing factors and substandard care factors were recoded into categorical variables.

Figure 2. Flowchart of pregnancy related deaths in Suriname

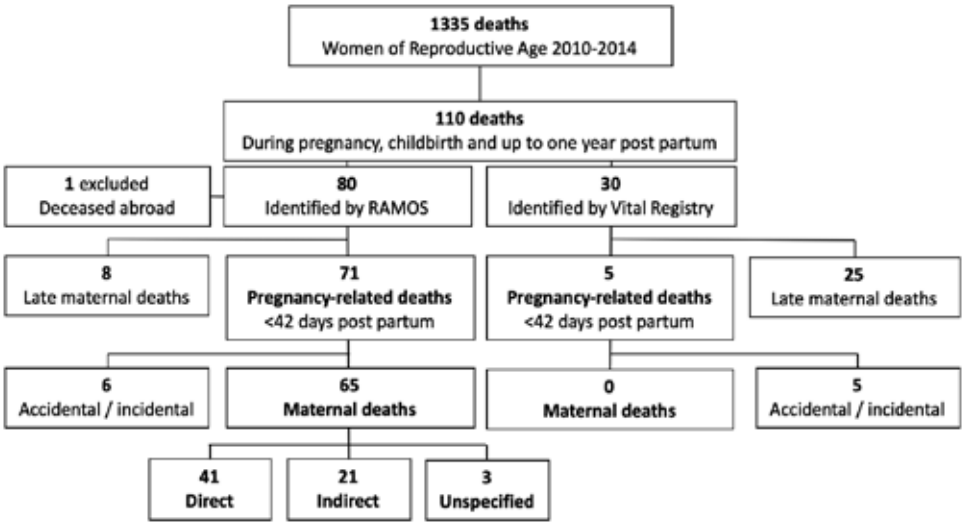


Table 1. Maternal deaths found by RAMOS in comparison to vital registration

	Area I Urban Paramaribo Wanica	**Area II** Urban Nickerie	**Area III** Rural coastal Coronie Saramacca Para Commewijne Marowijne	**Area IV** Rural interior Brokopondo Sipaliwini
General population, n=534.189	66 %	6 %	18 %	10 %
Live births, n= 50.051				
Residency	67 %	4 %	18 %	11 %
Location of delivery [1]	77 %	5 %	5 %	5 %
Maternal deaths, n=65				
Location of residence	40 (62)	4 (6)	10 (15)	11 (17)
Location of death	56 (86)	2 (3)	3 (5)	4 (6)
Hospital, n=55	53	2	N/A	N/A
Primary health care, n=5	-	-	3	2
Home, n=5	3	-		2
MMR per 100.000 live births	145	80	120	160

Legend

[1] Unknown location of live births in 8% (of which half of live births at home)

Table 2. Demographics of Surinamese population and of maternal deaths

	2010	**2011**	**2012**	**2013**	**2014**	**Total**
Live births	9712	9703	10217	10012	10407	**50051**
RAMOS						
MMR per 100.000 live births	154	144	69	130	154	**130**
Maternal deaths	15	14	7	13	16	**65**
Vital registration						
MMR per 100.000 live births	82	113	49	130	154	**106**
Maternal deaths	8	11	5	13	16	**53**
Underreporting	0	1	0	1	3	**5**
Misclassification of causes (%)	50	60	60	75	70	**65**
Misidentification (%)	47	28	30	8	18	**26**
Correction factor	1.88	1.40	1.40	1.08	1.23	**1.35**

RESULTS

Of the 1335 deceased women of reproductive age between 2010 and 2014, 71 were pregnancy-related and 65 were maternal deaths (figure 2). The 65 maternal deaths were identified among 50.051 live births, resulting in a MMR of 130 with an annual range from 69 to 154 per 100.000 live births (table 1).

Underreporting occurred by misidentification in 26% (n=17) and by misclassification in 65% (n=31) (table 1). The predictive value for the current vital registration to identify maternal deaths is 74% (48/48+17). The maternal deaths not identified by vital registration (n=17) occurred in the hospitals in 88% (n=15) or at home in 12% (n=2). The causes of these hospital-deaths were infectious diseases in 87% (n=13), admitted and deceased on non-obstetric wards. These death certificates did not indicate or suggest that the woman was or had been pregnant. Maternal deaths, which were identified by vital registration but were classified incorrectly, consisted of deaths without the cause mentioned on the death certificate (n=9), non-obstetric diseases (n=13), deaths complicated with more than one diagnosis (n=8) and cases in which the mode of death was reported on the death certificate rather than the underlying cause (n=17). Apart from the 48 true maternal deaths identified by vital registration, another five maternal deaths were incorrectly classified as maternal deaths (these were accidental or incidental causes or late maternal deaths).

Characteristics of maternal deaths: The women in Suriname who died during pregnancy, childbirth or puerperium lived in a rural coastal area or in the rural interior in respectively 18 and 11% (figure 1 and table 2). Maternal deaths, however, occurred in these areas in respectively 5 and 6%. Maternal deaths in urban hospitals (89%) occurred on the ICU (60%), ward (30%) or emergency or operating room (10%). Characteristics of maternal deaths are shown in table 3. Social insurance, indicating the (near) poor, covered 69% (n = 45) of the deceased women. Socially insured women were maroons or creoles in 75% (n = 34) of the cases. Anaemia (Hb $\leq$ 6.0 mmol/L) complicated 45% of the cases. Post-mortem investigation was performed in 3% (n = 2) of maternal deaths.

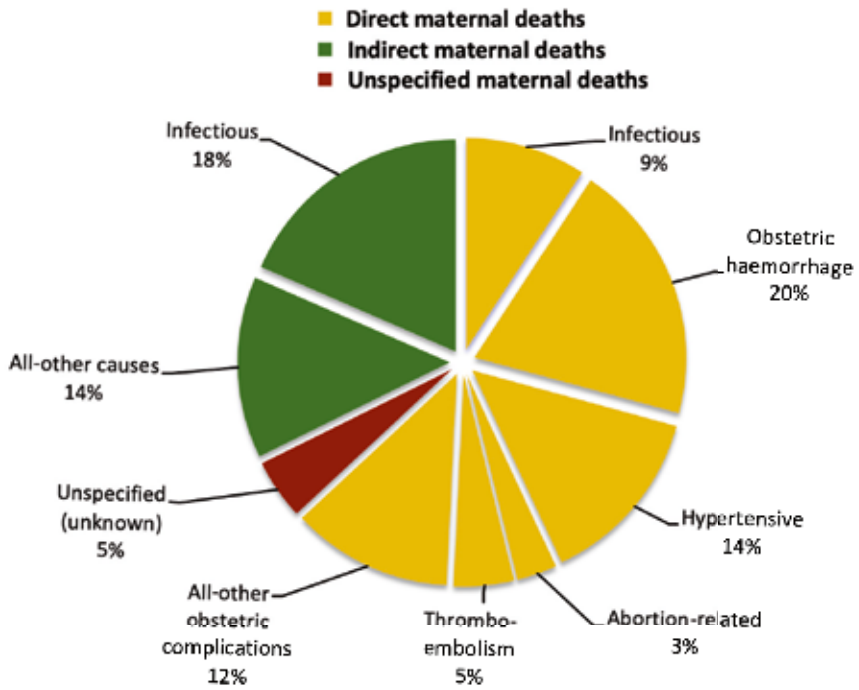
Table 3. Maternal characteristics of all maternal deaths

	n = 65 (%)
Age	
<20	11 (17)
20-35	42 (64)
36-50	12 (18)
Mean, range of age	29, 16-45
Ethnicity	
Hindu	12 (18)
Creole	13 (20)
Maroon	24 (37)
Javanese	8 (12)
Indigenous (Amerindians)	3 (5)
Mixed	5 (8)
Insurance (n=63)	
Social insurance (poor)	45 (69)
State Health	10 (15)
Private	8 (12)
Antenatal care (n=58)	
None	12 (23)
< 4	8 (15)
≥ 4	33 (62)
Parity at time of death (n=62)	
0	5 (8)
1	14 (23)
2	17 (27)
≥ 3	26 (42)
Pregnancy state	
Abortive < 16 weeks	5 (8)
Antepartum	15 (23)
Intrapartum	4 (6)
Post partum	41 (63)
Mode of delivery (n=41)	
Spontaneous, vaginal	25 (61)
Ventouse	3 (7)
Caesarean-section	13 (32)
Perinatal death (n=57)	
Yes	36 (64)
Intrauterine foetal death	8 (14)
Neonatal, within 7 days	8 (14)

Classification and causes of maternal deaths

Of the 65 maternal deaths, 41 (63%) were due to direct causes, 21 (32%) due to indirect causes and three (5%) maternal deaths were classified as unspecified because the cause of death was unknown (figure 3). The two leading causes of maternal mortality were obstetric and non- obstetric sepsis (n = 18, 27%) and obstetric haemorrhage (n=13, 20%). Obstetric haemorrhage was mainly due to postpartum haemorrhage (n=11, 85%) caused by uterine atony (29%), retained placenta (23%), ruptured uterus (15%), vaginal / cervical tear (8%), and unspecified causes (10%). Underlying cause of all ante partum haemorrhages was placental abruption (n=2, 15%). Hypertensive disorders and its complications (e.g. cerebral bleeding, HELLP, eclampsia) accounted for 14% of maternal deaths. However, hypertensive disorders, such as pregnancy induced hypertension and pre-eclampsia, were diagnosed in 30% of all maternal deaths. Though not the underlying cause of death, they were commonly classified as a contributing factor.

Figure 3. Classification of underlying causes of the maternal deaths (n=65)



The remaining other causes of direct maternal deaths (n=8, 12%) were four probable amniotic fluid embolisms, one obstructed labour, one suicide by intoxication at 24 weeks, one case of acute fatty liver of pregnancy with consequently hepatic encephalopathy and multi- organ failure. The underlying cause of one case remained unknown as the woman died without any reported symptoms within a few hours after caesarean section for foetal indication. Sepsis occurred either due to direct obstetric complications (9%) of which one third had puerperal sepsis while being HIV positive or due to medical conditions aggravated by the pregnancy (e.g. non-obstetric septicaemia, pneumonia, gastro-enteritis, AIDS) and therefore were classified as indirect maternal deaths (18%). The other non-sepsis indirect maternal deaths (n=9) concerned two cases of endocarditis resulting in heart failure, one pulmonary bleeding caused by idiopathic thrombocytopenia, one case of end-stage renal failure due to diabetes and one woman, with pre- existent hypertension, died due to a cerebrovascular accident.

Table 4. Substandard care factors analysed in maternal deaths (n=59)

	n= (%)
Substandard care present	56 (95)
Professional factors	
Quality	47 (80)
Availability	11 (19)
Attitude / work-ethic	13 (22)
Medical service factors	
Wrong or delay in diagnosis	35 (59)
No/wrong treatment	46 (78)
Poor monitoring	35 (59)
Communication	19 (32)
Unavailability medical supplies	
Lack of diagnostic equipment	8 (14)
ICU-bed needed (n=45)	11 (24)
Blood necessary (n=31)	10 (32)
Lack of medication, oxygen-therapy, crash-cart	12 (20)
Patient factors	
Poor compliance to treatment	13 (22)
Refusing treatment	4 (7)
Delay in transportation	9 (15)

Substandard care factors were found in 95% (n=56/ 59) of the cases (table 4). More than 5 substandard care factors were present in 55% of cases. In 80% of the cases care provided by health professionals was below the standard due to delay in diagnosis (59%), inadequate treatment (78%) or poor monitoring (59%). Blood transfusion was unavailable in 10 of 31 cases (32%) when this was required. An ICU bed was not available when requested in 11 (24%) of 45 cases. The committee agreed that in 47% of the maternal deaths substandard care factors certainly (21%) or most likely (26%) led to death.

DISCUSSION

The MMR in Suriname is 130 per 100,000 live births between 2010 and 2014. Mungra et al. reported a MMR of 226 between 1991 and 1993, which indicates a 42% reduction in maternal deaths and an improvement in underreporting from 64% to 26%.[4,5] A comparison of the MMR and underreporting is difficult, as to our best knowledge there are few countries that have performed a RAMoS of confidential enquiry.[16-19]

Though our study suggests that, over the years, there is a growing reliability on identification of maternal deaths, the underreporting rate in Suriname (26%) is still higher than reported in Jamaica (20%), Argentina (9.5%) and Mexico (13%).[16-19] The underreporting due to misidentification of maternal deaths in Suriname can be explained by numerous facts: first, physicians are not obliged to report maternal deaths. Second, part of the death certificate (including the cause of death) is not always available as it is not obliged to be completed before the burial takes place. Third, the death certificate does not include a pregnancy checkbox and finally no active enquiry or RAMoS is per- formed. The effectiveness of a pregnancy check box on death certificates has proven to be effective in identifying pregnancy-associated mortality.[20,21] Misclassification of deaths by vital registration in Suriname can be explained by different factors. First, maternal death causes are designated by the ICD-code on the death certificate (patient records frequently unavailable), while the ICD- MM coding alone is considered inadequate.[22] Second, post-mortem investigations are rare. Third, verbal autopsies and maternal death reviews are not

performed to identify causes. These last strategies are best in identifying causes and evaluating quality of care in order to improve.[11,14,15,22]

Social insurance as a marker indicating poverty was found in the majority of maternal deaths (69%), while less than half of the general population had social insurance. A difference in ethnicity is seen between the general female population (Hindustani 28%; Maroon 24%; Mixed 14%) and the maternal deaths (Hindustani 18%; Maroon 37%; Mixed 8%).

Similar to two decades ago, obstetric haemorrhage is the most common direct cause of death, which is lower than reported in low-income countries (27%) and higher than in high-income countries (16%).[3] Hypertensive disorders are known to be an important cause of maternal deaths in Latin America and the Caribbean (22%).[1-3] While eclampsia was the underlying cause in just 14% of the deaths in Suriname, it was an important contributing factor (30%) to deaths with another underlying cause. The authors advise health authorities to implement nation- wide protocols for the prevention and management of hypertensive disorders and postpartum haemorrhage. Illegal abortion is the cause of death in only one case (1.5%), which is in great contrast to the 12% abortion-related deaths in Latin America and the Caribbean.[3,17,19] Although illegal in Suriname, most abortions are self-induced with misoprostol and women present with an incomplete abortion after which safe surgical evacuation is performed in the hospital by a gynaecologist or gynaecologist in training. However, since termination of pregnancy is not registered, underreporting could have occurred. Indirect maternal deaths (32%), in particular non-obstetric sepsis (18%), accounted for a greater part of the maternal deaths in our study compared to the 27% of other Latin American and Caribbean countries.[3] Therefore, we recommend that these maternal deaths from should be analysed in detail to gain more knowledge of underlying causes, circumstances and preventive measurements.

The most striking finding of our survey is that the majority of maternal deaths occurred in hospital (85%) with the most important substandard care factor being delay in diagnosis (59%) and delay in treatment by health care providers, and less frequently due to patient delay (15%). This finding necessitates actions such as

training and retaining skilled staff and implementation of evidence- based guidelines. Another important finding is that most of the deaths occurred postpartum, indicating that improvements can be made in the care provided in the period after birth. Patients should be provided with more information. We advise more frequent and qualitative better postnatal checks and if necessary, home-visits should be performed. Lastly, a great number of maternal deaths occurred on the wards (30%) and the monitoring of patients is found to be inadequate in 59% of these cases. Implementation of an early warning system for timely interventions in order to reduce serious adverse events has been proven effective and is recommended.[23]

Limitations of this study are indwelled in its retrospective nature. Though we performed a robust enquiry, maternal deaths could have been missed, especially if they occurred outside of health care facilities or during early pregnancy. In addition, not all case files were available, records were often incomplete and post-mortem investigations were generally not performed. This affected the quality of the classification of causes and evaluation of substandard care during the maternal death reviews. Fi- nally, but most importantly, due to lack of national data on characteristics of the pregnant population, pregnancy and delivery, we were not able to perform multivariate analysis and assess risk factors.

CONCLUSION

Suriname has a high MMR compared to other Latin American countries and the Caribbean with similar or lower income economies. We highly recommend (1) to improve national data surveillance, (2) install a maternal mortality committee to review all maternal deaths, (3) implement an early warning score and national guide- lines on postpartum haemorrhage and eclampsia and (4) improve postnatal care strategies. Lastly, as maternal mortality is merely the tip of the iceberg, severe morbidity research should be conducted to assess and prevent severe obstetric complications and make progress to reach the SDG of a MMR <70 in 2030.

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Classifying maternal deaths in Suriname using WHO ICD-MM; different interpretation by physicians, national and international maternal death review committees

4

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Abstract

Background: Insight into the underlying causes of pregnancy-related deaths is essential to develop policies to avert preventable deaths. The WHO International Classification of Diseases-Maternal Mortality (ICD-MM) guidelines provide a framework to standardise maternal death classifications and enable comparison in and among countries over time. However, despite the implementation of these guidelines, differences in classification remain. We evaluated consensus on maternal death classification using the ICD-MM guidelines.

Methods: The classification of pregnancy-related deaths in Suriname during 2010-2014 was compared in the country (between the attending physician and the national maternal death review (MDR) committee), and among the MDR committees from Suriname, Jamaica and the Netherlands. All reviewers applied the ICD-MM guidelines. The inter-rater reliability (Fleiss kappa [κ]) was used to measure agreement.

Results: Out of the 89 cases certified by attending physicians, 47% (n=42) were classified differently by the Surinamese MDR committee. The three MDR committees agreed that 18% (n=16/89) of these cases were no maternal deaths, and, therefore, excluded from further analyses. However, opinions differed whether 15% (n=11) of the remaining 73 cases were maternal deaths. The MDR committees achieved moderate agreement classifying the deaths into type (direct, indirect and unspecified) (κ=0.53) and underlying cause group (κ=0.52). The Netherlands MDR committee classified more maternal deaths as unspecified (19%), than the Jamaican (7%) and Surinamese (4%) committees did. The mutual agreement between the Surinamese and Jamaican MDR committees (κ=0.69 vs κ=0.63) was better than between the Surinamese and the Netherlands MDR committees (κ=0.48 vs κ=0.49) for classification into type and underlying cause group, respectively. Agreement on the underlying cause category was excellent for abortive outcomes (κ=0.85) and obstetric haemorrhage (κ=0.74) and fair for unspecified (κ=0.29) and other direct causes (κ=0.32).

Conclusions: Maternal death classification differs in Suriname and among MDR committees from different countries, despite using the ICD-MM guidelines on similar cases. Specific challenges in applying these guidelines included attribution of underlying cause when comorbidities occurred, the inclusion of deaths from suicides, and maternal deaths that occurred outside the country of residence.

BACKGROUND

The maternal mortality ratio (MMR) is a robust indicator of health care quality, inequality and inequity in and among countries.[1] Most maternal deaths are preventable in low, middle and high resource settings, as was the case for 47% of maternal deaths in Suriname between 2010 and 2014.[2,3] To develop prevention strategies, accurate data on the number of maternal deaths and insight into underlying causes are essential.[2,4,5] However, the assignment of a reliable underlying cause of death and the subsequent classification can be a challenge.[6]

The World Health Organization (WHO) aimed to create uniform maternal death classification guidelines to enhance usability, improve comparability and decrease coding errors.[7-9] Therefore, the WHO launched the International Classification of Diseases-Maternal Mortality (ICD-MM) in 2012, an application of International Classification of Diseases-10th edition (ICD-10) to classify deaths during pregnancy, childbirth and the puerperium.[7]

Difficulties in attributing the underlying causes can result in inconsistencies in classification in and among countries, despite using the ICD-MM guidelines.[8,10] When a European expert panel reviewed pregnancy-related deaths across 13 European countries, they identified 14% more maternal deaths than what the national registries of the individual countries included.[11] Classification is especially complicated when comorbidities occur, and the start of the chain of events resulting in maternal death has to be determined.[10] Consequently, underlying cause attribution may vary, or the causes are unknown or unclear, resulting in underreporting. This is not only an issue in low- and middle income countries but also in high-income countries and was reported by various Maternal Death Review

(MDR) committees, including those from Suriname, Jamaica and the Netherlands.[3,12,13]

Therefore, this study aimed to assess the applicability of the ICD-MM guidelines by investigating the classification of maternal deaths in one country and across three countries. First, the cause of death as determined by the attending physician was compared to the assessment of the Surinamese MDR committee. Second, cases were shared with the national MDR committees from Jamaica and the Netherlands, and their assessments were compared to the findings of the Surinamese MDR committee. Following these findings, the classification difficulties are discussed, and recommendations for improving the ICD-MM guidelines' applicability and international comparability of maternal mortality are provided.

METHODS

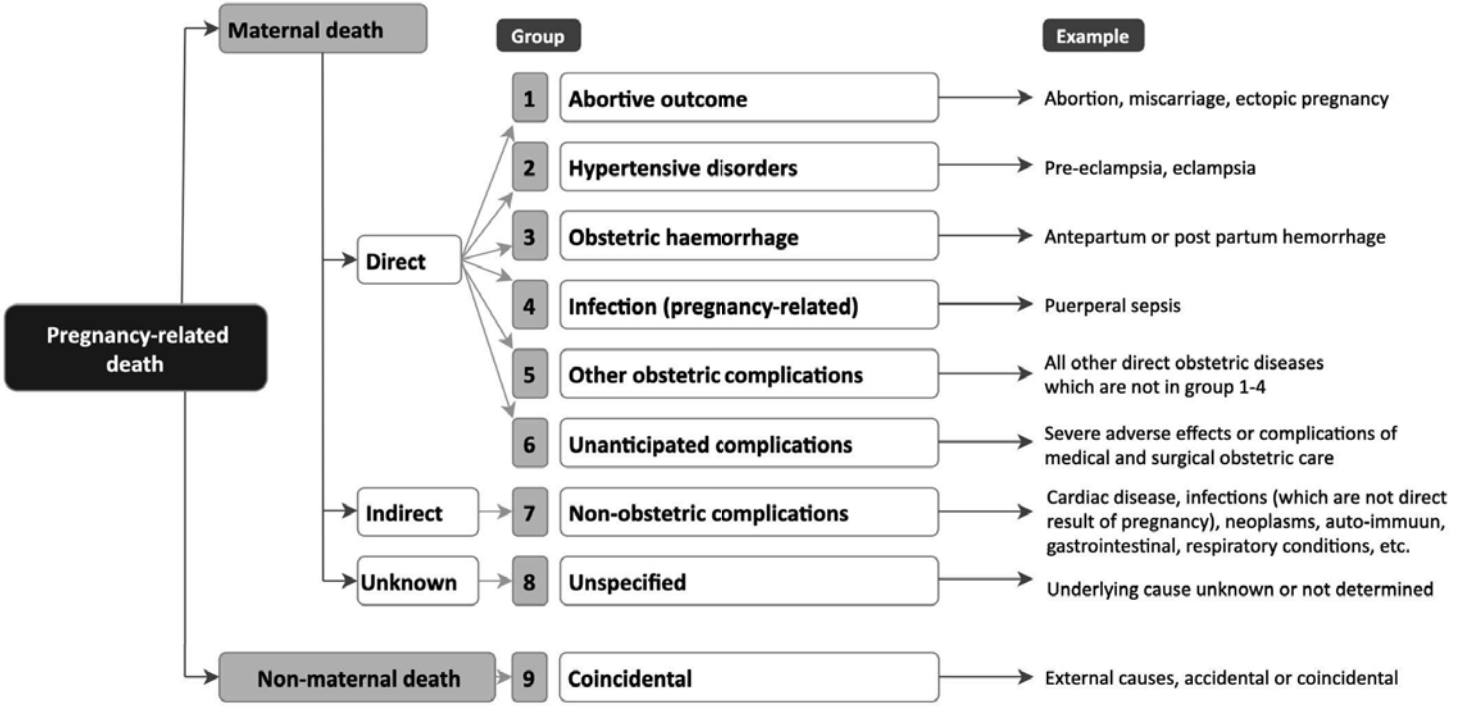
Study design: A population-based reproductive age mortality survey (RAMoS) was conducted in 2015 to identify pregnancy-related deaths in Suriname between 2010 and 2014.[3] A total of 89 possible maternal deaths were identified and reviewed by the national MDR committee of Suriname, Jamaica (both middle income countries) and the Netherlands (high-income country).

Settings: Suriname is an upper middle income South American country on the Caribbean coast with 570,496 inhabitants in 2017.[14,15] Out of the approximately 10,000 births annually, 86% occur in five hospitals, 6% in primary care centres and the remaining 8% deliver at home or is not registered.[16] When death occurs, the attending physician in Suriname has an obligation to complete a death certificate documenting the causes and circumstances of the death. The Bureau of Public Health codes the cause of death using ICD-10.[3,17] A national MDR committee was established to audit and classify the pregnancy-related cases. The committee consisted of specialists in obstetrics, internal medicine, midwifery and, on request, other specialists such as cardiologists, intensive care specialists and neurologists were invited. Classification was consensus-based, and according to the WHO ICD-MM guidelines.[3]

Jamaica, a Caribbean island nation with 2.9 million inhabitants, is an upper middle income country.[18] Their MDR committee was established in 1998, and classified maternal deaths according to the ICD-MM.[12] Three members from this multidisciplinary committee (midwives, obstetricians, epidemiologists, public health practitioners, and pathologists), volunteered to review the Surinamese cases: a reproductive health epidemiologist and two obstetricians.
The Netherlands is a high-income country with 17.3 million inhabitants.[19] The MDR committee of the Dutch Society of Obstetricians and Gynaecology, was established in 1981 and currently uses the ICD-MM guidelines for maternal death classification.[13] Seven committee members classified the pregnancy-related deaths of this study independently. In case of uncertainty or unclarity, cases were discussed with other members to achieve consensus on the final classification.

Definitions: Pregnancy-related deaths occur during pregnancy, delivery and puerperium. Maternal deaths are defined as those occurring during pregnancy or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, where the cause of death is related to or aggravated by pregnancy or its management, not from coincidental or accidental causes.[7] Direct deaths are due to obstetric complications, while indirect deaths result from non-obstetric pre-existing diseases, or diseases developing during pregnancy, that is aggravated by the physiologic effects of pregnancy. If the underlying cause is unknown or undetermined, the death is classified as unspecified. Coincidental deaths are deaths that occur during pregnancy, childbirth and puerperium due to external causes that are not related to the pregnancy. Each pregnancy-related death can be assigned to one of nine groups: group 1-6 (direct deaths), group 7 (indirect deaths), group 8 (unspecified deaths), or group 9 (coincidental deaths) (figure 1).[7] The underlying cause of death is the disease or condition that initiated the chain of events leading to death.[6,7]

Figure 1. Groups of underlying causes of death during pregnancy, childbirth and the puerperium in mutually exclusive, totally inclusive groups[7]



Data collection and analysis: Pregnancy-related deaths (n=89) occurring in Suriname between 2010 and 2014 were identified by a Reproductive Age Mortality Survey (RAMoS).[3] Medical files were summarised, and the underlying causes of death, as attributed by the attending physicians, were extracted from the available death certificate. All possible pregnancy-related deaths were audited by the Surinamese MDR committee and classified according to the ICD-MM.[3] In Suriname, we compared the underlying cause attributed by the attending physicians (documented on the death certificate or in the medical record) to the findings of the national MDR committee.

The Jamaican and Dutch MDR committees reviewed and classified the same 89 pregnancy-related deaths into maternal death or not, type of maternal death and one of the nine ICD-MM groups. Cases classified as not maternal by all three review teams were excluded from further analysis. The classification in type of death (direct, indirect and unspecified) and the WHO group of underlying cause were compared, using correlation analysis to assess agreement among the three review teams (IBM SPSS version 24.0; Armonk, New York, USA). The inter-rater reliability (IRR) was calculated by Fleiss kappa (for three raters). The kappa (κ) value range from −1 to +1, where 0 represents no agreement and one perfect agreement. Negative values indicate that the observed agreement is less than that expected from chance alone.[20] A κ below 0.2 indicates poor agreement and above 0.8 very good agreement. The overall value of kappa is the weighted average of the individual kappa value per category. A p-value < 0.05 only indicates that agreement between raters is significantly better than expected by chance.[20,21] Discrepant cases were described to highlight sources of disagreement and facilitate further refinement of regional and global guidelines.

We performed two sensitivity analyses to evaluate the agreement across the MDR committees in type and underlying cause attribution. First, we excluded mortality cases that were not classified as maternal deaths by at least one MDR committee. Next, we assessed whether agreement on type and underlying cause attribution was better for maternal deaths with complete files.

Table 1. Pregnancy-related deaths lacking consensus among maternal death review (MDR) committees whether to classify as maternal deaths

Case	Gestation	Case description; cause of death	Classified as a maternal death by		
			Suriname	Jamaica	Netherlands
Doubt in classification of suicide in early pregnancy					
1	Unknown	Gramoxone[1] auto-intoxication	**No**	**Yes**	**No**
2	7 weeks	Gramoxone[1] auto-intoxication	**No**	**Yes**	**Yes**
3	9 weeks	Gramoxone[1] auto-intoxication	**No**	**Yes**	**Yes**
Doubt regarding evidence of pregnancy					
4	N/A	Following a curettage, chest pain and dyspnoea developed. Curettage pathology report showed no evidence of pregnancy.	**No**	**No**	**Yes**
5	N/A	Died at home from unknown cause. Verbal autopsy with family: early pregnancy. Examination: no fundal height palpable, but peripheral oedema of both feet.	**Yes**	**Yes**	**No**
6	N/A	Died in transit to hospital. Patient complained of abdominal pain, vaginal blood loss and chest pain. Verbal autopsy with family: could be pregnant.	**No**	**Yes**	**Yes**
Doubt whether the death was maternal or coincidental					
7	25 weeks	Severe burn wounds after explosion	**No**	**No**	**Yes**
8	29 weeks	Sepsis, meningoencephalitis/cerebral abscess	**Yes**	**Yes**	**No**
9	34 days postpartum	Sepsis with symptoms of high fever and diarrhoea	**Yes**	**No**	**Yes**
10	35 days postpartum	Normal delivery. Cause of death unknown.	**No**	**Yes**	**Yes**
Doubt in classification of maternal death of a local resident in another country					
11	29 weeks	Admitted in a Surinamese hospital with a severe sickle cell crisis. Ten days after discharge she died in neighboring French Guyana.	**No**	**Yes**	**No**

Legend: [1] Gramoxone is the tradename of paraquat, a contact herbicide, highly toxic to humans

RESULTS

Out of 89 pregnancy-related deaths, 53 (60%) medical files were complete, 14 (16%) were unavailable, and 22 were incomplete. The three MDR committees utilised all available information to analyse the 89 deaths.

Classification in Suriname: attending physicians vs national MDR committee

In 42 (47%) of 89 pregnancy-related deaths the cause attributed by the attending physician and the MDR committee differed; seventeen had no underlying cause attributed by the attending physician, and in 25 cases, different causes were concluded by the MDR committee. Differences were mostly due to the mode of death or symptoms having been recorded as the underlying cause. Two autopsies had been performed, one on a possible late maternal death and another on a woman who had developed a pulmonary embolism after a placental abruption.

Classification MDR committees Suriname, Jamaica and the Netherlands

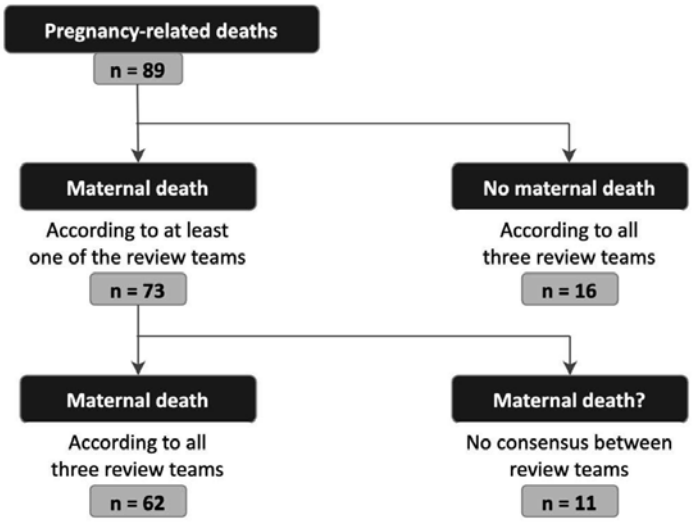
Maternal death classification

The Surinamese MDR committee classified 65 deaths as maternal, the Jamaican MDR committee 70 and the Netherlands MDR committee 69. Based on 50,051 live births in the audited period, this corresponded with an MMR of 130, 140 and 138 per 100.000 live births, respectively. The three MDR committees agreed unanimously that 18% (n=16/89) of the pregnancy-related deaths were not maternal deaths: 12 late maternal deaths, two coincidental deaths and two with negative pregnancy tests (supplementary file 1). Exclusion of these cases resulted in a total of 73 cases, used for further analyses (figure 2). However, opinions differed in 15% (n=11/73) of the cases (table 1).

Type of maternal deaths (direct, indirect and unspecified)

Of the 73 cases considered as maternal deaths by at least one MDR committee, classification into type of maternal death differed for 31 (42%) cases. The overall kappa was 0.53 (95% CI 0.44 - 0.62); $p < 0.001$ and was only fair for the unspecified category ($\kappa = 0.29$ (95% CI 0.16 – 0.43); $p < 0.001$) (table 2).

Figure 2. Flowchart of pregnancy-related deaths classified by MDR committees



The Netherlands committee (19%, n=14/73) classified more cases as unspecified compared to Surinamese (4%, n=3/73) and Jamaican committees (7%, n=5/73) (table 2 and supplementary file 2). Agreement between the MDR committees of Suriname and Jamaica (κ = 0.69 (95% CI 0.53 – 0.86); p < 0.001) was higher than between the committees of Suriname and the Netherlands (κ = 0.48 (95% CI 0.32 – 0.63); p < 0.001) (table 2). Out of 41 maternal deaths classified as direct by the Surinamese committee, the Jamaican committee classified five cases differently (four indirect, one unspecified), while the Dutch committee classified ten cases otherwise (three indirect, seven unspecified).

WHO ICD-MM groups of underlying causes

Table 3 compares the underlying causes of maternal deaths according to the nine ICD-MM groups as classified by the three MDR committees. Table 4 summarises levels of agreement between the three MDR committees for each ICD-MM underlying cause group. The overall kappa was 0.52 (95% CI 0.47–0.58); p < 0.001, with the highest agreement for abortive outcomes (κ = 0.85) and obstetric haemorrhage (κ = 0.74) and the lowest for the unspecified (κ = 0.29) and other direct causes (κ = 0.32).

Table 2. Agreement among Maternal Death Review (MDR) committees in classification into the type of maternal death, n=73 (100%)

	MDR committees		
	Suriname	**Jamaica**	**The Netherlands**
	n (%)	n (%)	n (%)
Direct	41 (56)	41 (56)	36 (49)
Indirect	21 (29)	24 (33)	19 (26)
Unspecified	3 (4)	5 (7)	14 (19)
Not Maternal	8 (11)	3 (4)	4 (6)

Kappa = 0.53 (95% CI 0.44 - 0.62); p <0.001

Jamaican MDR committee		**Direct**	**Indirect**	**Un-specified**	**Not Maternal**	***Total Jamaica***
	Direct	36	1	0	4	***41***
	Indirect	4	19	0	1	***24***
	Unspecified	1	0	3	1	***5***
	Not Maternal	0	1	0	2	***3***
	Total Suriname	***41***	***21***	***3***	***8***	***73***

Kappa = 0.69 (95% CI 0.53 - 0.86); p<0.001

The Netherlands MDR committee		**Direct**	**Indirect**	**Un-specified**	**Not Maternal**	***Total Netherlands***
	Direct	31	3	0	2	***36***
	Indirect	3	14	0	2	***19***
	Unspecified	7	3	2	2	***14***
	Not Maternal	0	1	1	2	***4***
	Total Suriname	***41***	***21***	***3***	***8***	***73***

Kappa = 0.48 (98% CI 0.32 - 0.63); p<0.001

Agreement between the Surinamese and Jamaican MDR committees was higher (overall κ = 0.63; 95% CI: 0.53 – 0.73); p < 0.001 than between the Surinamese and Dutch committees (overall κ = 0.49; 95% CI: 0.39 – 0.59); p < 0.001. The lowest agreement between the Surinamese and the Jamaican MDR committees was for other direct obstetric causes (κ = 0.36) and highest for obstetric haemorrhage (κ = 0.79) and indirect deaths (κ = 0.78). Agreement was poor between the Surinamese and the Dutch MDR committee for unspecified (κ = 0.14) and other direct deaths (κ = 0.25).

The sensitivity analyses on the agreement between the MDR committees in type and underlying causes was performed on 62 cases (by excluding all mortality cases that were assessed as being not maternal). These showed slightly better overall agreement for classification in type of maternal death (κ = 0.61 vs 0.53) and underlying cause (κ = 0.58 vs 0.52) compared to the primary analysis (supplementary file 3). Fifty-three maternal death cases had complete files. Analysis of only the cases with complete files also showed better overall agreement for classification in type of maternal death (κ = 0.69 vs 0.53), and underlying cause (κ = 0.58 vs 0.52) than the primary analysis.

Evaluation of the level of agreement for the ICD-MM underlying cause among the MDR committees showed better agreement between Suriname and Jamaica (κ = 0.69 vs 0.66) than between Suriname and the Netherlands (κ = 0.54 vs 0.53) when applied to the 62 maternal deaths, as well as when applied to the 53 complete files respectively (supplementary file 3).

Table 3. Classification of maternal deaths underlying causes according to the ICD-MM by the three maternal death review (MDR) committees, n=73 (100%)

	Suriname n (%)	**Jamaica** n (%)	**The Netherlands** n (%)
Direct			
1. Abortive outcomes	2 (3)	3 (4)	2 (3)
2. Hypertensive disorders	7 (10)	11 (15)	6 (8)
3. Obstetric haemorrhage	13 (18)	16 (22)	14 (19)
4. Infection (pregnancy-related)	6 (8)	2 (3)	5 (7)
5. Other obstetric complications	13 (18)	9 (12)	9 (12)
6. Unanticipated complications	-	-	-
Indirect			
7. Non-obstetric complications	21 (29)	24 (33)	19 (26)
Unknown			
8. Unspecified	3 (4)	5 (7)	14 (19)
Not maternal			
9. Coincidental	8 (11)	3 (4)	4 (6)

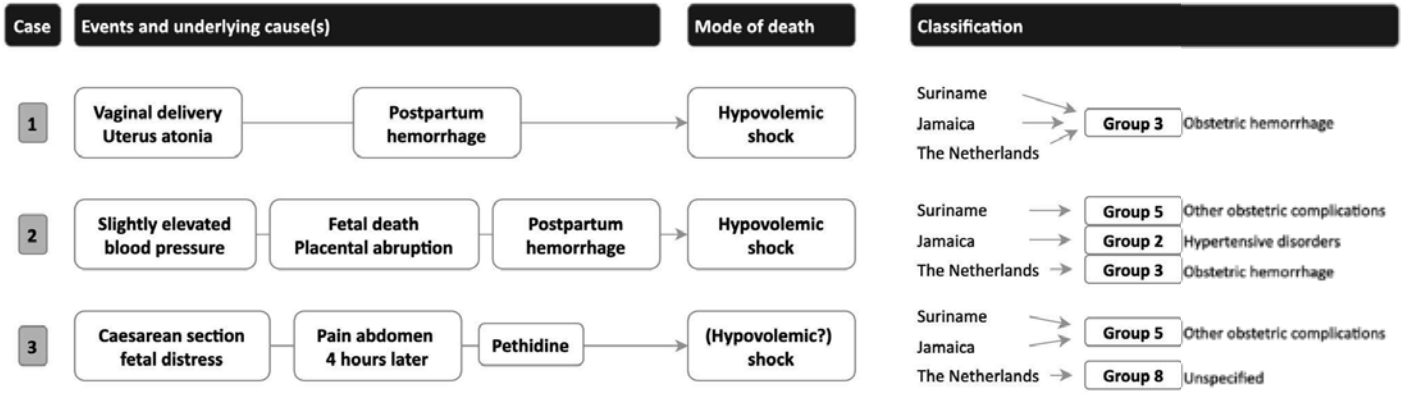
Table 4. Level of agreement of underlying causes according to WHO ICD-MM by MDR committees of Suriname, Jamaica and the Netherlands

Levels of Agreement	Suriname, Jamaica and Dutch MDR committee	Surinamese and Jamaican MDR committee	Surinamese and Dutch MDR committee
Almost perfect Kappa ≥ 0.81	Abortive outcomes	-	Abortive outcomes
Substantial Kappa 0.61 - 0.80	Obstetric haemorrhage Indirect	Abortive outcomes Hypertensive disorders Obstetric haemorrhage Indirect Unspecified	Obstetric haemorrhage
Moderate Kappa 0.41 - 0.60	Hypertensive disorders Obstetric infection	Obstetric infection	Hypertensive disorders Obstetric infection Indirect
Fair Kappa 0.21 - 0.40	Unspecified Other direct obstetric	Other direct obstetric	Other direct obstetric
Poor / Slight Kappa < 0.20	-	-	Unspecified

Morbid events leading to death

Consensus among the Surinamese, Jamaican and Dutch committees was fair for the other direct obstetric causes, with three cases identically classified (two presumed amniotic fluid embolisms, one suicide at 24 weeks) (table 4 and supplementary file 4). The cases with discrepancies in groups of underlying cause were characterised by either multiple comorbidities and longer chain of events or rapidly evolving death without opportunities for additional diagnostic evaluation (figure 3).

Figure 3. Maternal death classification difficulties in simple and complex chain of events



DISCUSSION

This study explored consistency in classifying pregnancy-related deaths in Suriname at two levels. First, underlying cause attribution by the attending physicians, and the Surinamese MDR committee was compared; conclusions differed in 47% of cases. Second, the classification of three national MDR committees of Suriname, Jamaica and the Netherlands were compared applying the WHO ICD-MM guidelines to the same cases. There was 15% disagreement among these committees on whether selected pregnancy-related deaths met the criteria to be defined as maternal deaths. They achieved moderate agreement (k = 0.53) on classifying cases as direct, indirect or unspecified, with greater consensus between the Surinamese and Jamaican MDR committees (k = 0.69) than the Surinamese and Netherlands MDR committees (k = 0.48). The MDR committee of the Netherlands, a high-income country, classified more deaths as unspecified than those from the middle income countries of Suriname and Jamaica. There was higher concurrence among the three MDR committees in underlying cause attribution to abortive outcomes, obstetric haemorrhage and indirect maternal deaths, but only fair agreement on a mix of cases (other direct obstetric causes and unspecified).

The large difference (47%) in underlying cause attribution for maternal death between the attending physicians and the Surinamese MDR committee is not unusual. Similar differences were also seen in Malawi, where poor agreement between healthcare providers and the research team on maternal death classification was reported.[22] Another study found a 40% difference in underlying cause attribution in a multi-country survey that compared health provider findings with external reviewers among Low- and Middle income Countries (LMIC).[6] The abovementioned examples illustrate the importance of multidisciplinary case discussion and consensus-based underlying cause attribution.

Besides inconsistent underlying cause attribution, poor coding of pregnancy-related deaths, misidentification, or misclassification can result in inadequate certification and is associated with underreporting.[2,12,23] Due to underreporting, vital statistics could miss at least 50% of the maternal deaths.[24] Hence, since maternal death certificates are also completed by non-obstetricians (e.g. in the

rural interior or when indirect maternal deaths occurred), all clinicians would benefit from training to correctly complete death certificates.

The MDR committees in our study encountered specific challenges for which no clear guidance was available from the ICD-MM guidelines. These included (1) determining the fact of pregnancy with limited evidence; (2) inclusion of deaths from suicide, especially in early pregnancy and (3) whether and how to count maternal deaths outside the country of residence. It is unclear what the minimally acceptable evidence of pregnancy should be without medical confirmation and under which circumstances information from verbal autopsy alone could be used to confirm pregnancy. While the ICD-MM classifies suicide during pregnancy and puerperium as a direct maternal death, this is clearer for puerperal psychosis and postpartum depression than for events early in pregnancy.[7] The trigger for suicide may be social/circumstantial (partner rejection, domestic violence, unintended pregnancy), rather than clinical (pre-existing mental disorder or hormonal changes impacting mental health).[25,26] In addition, the ICD-MM guidelines do not elaborate on how to classify maternal deaths from suicide (direct vs indirect) when underlying mental disorders existed.[25] Finally, opinions differed in this study on the inclusion of a resident who had been under local care but died in another country. As no global guidance exists on whether to count such events in the country where the women dies or the country of residence, there is a chance that these cases are not reported at all (excluded in the country where she died and not reported in the country where she lived). Since all births are included in the national birth registry (denominator), we suggest including the mother also in the country where she died (numerator). Importantly, in these situations, information is ideally exchanged between countries to facilitate local reporting and sharing of "lessons to be learned".

Consensus between the MDR committees of Suriname and Jamaica was higher than between those of Suriname and the Netherlands. The cases the Dutch committee considered unspecified but were assigned other diagnoses by the other committees had limited information on the disease course, and lacked confirmatory diagnostic tests such as laboratory results, ultrasounds, Computed Tomography (CT) or

Magnetic Resonance Imaging (MRI) scans compared to the cases with more agreement. Advanced diagnostics were often unavailable due to financial or logistic constraints, such as the minimal laboratory capacity in the rural interior areas. In these cases, the MDR committees in LIMCs must often rely on clinical judgement to make a diagnosis. Practicing medicine with greater uncertainty regarding diagnosis and treatment outcomes and fewer possibilities to provide evidence-based care is more commonplace in LMICs and possibly explains the more consistent results between the MDR committees of the two middle income countries.

Classification into type of maternal death (direct, indirect and unspecified) differed in 42% of cases, only achieving moderate agreement among the three MDR committees. Dividing maternal deaths into direct and indirect conditions is pragmatic as preventive programs to avert direct deaths differ from indirect deaths.[27] However, this division has been questioned by the MDR committees in the United Kingdom (UK) and the Netherlands, especially for women with concurrent direct and indirect comorbidities.[28] In both middle and high-income countries, several pre-existing conditions such as obesity, diabetes mellitus, and hypertensive diseases are increasing and the risk of pregnant women to develop direct and indirect complications of pregnancy (e.g. postpartum haemorrhage, eclampsia, cardiovascular diseases).[28-30] This coexistence of multiple conditions in an individual is known as multimorbidity and is one of the challenges of modern medicine.[31,32] These conditions obfuscate the strict demarcation between direct and indirect deaths and reduce their relevance. Instead, adding multimorbidity categories, such as (non)communicable diseases and (pre-existing) mental disorders to the ICD-MM guidelines would be more pertinent.

We conducted a sensitivity analysis to explore whether consensus improved with the exclusion of (1) cases without consensus among the MDR committees in the classification as maternal deaths, and (2) cases with incomplete information. As expected, the exclusion of the cases with uncertainty improved the level of agreement. These exclusions strengthened the consensus that already existed between the Surinamese and Jamaican MDR committees. However, since

differences are small, these analyses suggest that, even with limited information, MDR committees can reach reliable conclusions on the probable types and underlying causes of maternal deaths.

Our data showed that when the cycle of events leading to death had fewer incidents (figure 3), underlying cause attribution was more straightforward (as with abortion-related and obstetric haemorrhage). Selecting the initiating event from a chain of multiple events is more difficult in complex cases, resulting in a discrepancy in underlying cause classification in our study. Two high-income countries, the United Kingdom (UK) and the Netherlands, also reported such differences in underlying cause attribution.[10] Their MDR committees discussed selected cases where disagreement was expected during a meeting attended by most members of both committees. While the Netherlands classified a death by the primary underlying pathology, the UK more pragmatically focused on the acute fatal complication.[10] They suggested that decision-making may be guided by what best informs local practice in the absence of global guidance. However, this approach could result in heterogeneity and complicates comparison among countries.

Reliable underlying cause attribution may be improved by combining clinical data with autopsy findings.[33,34] However, autopsy for maternal death is seldom performed in low resource countries such as Suriname, where only two cases were investigated.[3] It may be useful to revisit verbal autopsy techniques to improve collection and interpretation of information on signs, symptoms and risk factors.[35] Another possible option is the minimally invasive autopsy. This includes collection of blood, cerebrospinal fluid and tissue samples for histologic and microbiologic analysis.[36] This option could be explored to assist in identifying the underlying causes of maternal death.

Strengths and limitations: This study's strength is its unique comparison of the classification of the same cases by physicians and (inter)national MDR committees from three different settings applying the WHO ICD-MM guidelines. Limitations include difficulties in interpreting cases with limited information and, possibly, by

a high-income country being unfamiliar with the different contexts of LMIC. The inter-rater reliability should be carefully interpreted as the overall kappa may not be reliable for rare observations, such as group 1 (abortive outcomes) and group 4 (pregnancy-related infections).

CONCLUSION AND RECOMMENDATION

This is the first study comparing audit and ICD-MM classification of the same maternal deaths by MDR committees of different countries, revealing the difficulties and challenges. Accurately completing the death certificate, training in performing audits and applying the WHO ICD-MM guidelines to code and classify the death should be encouraged.[12,19] We suggest that the WHO guidelines should elaborate more on the following aspects:

1. Clearly define and describe how to classify suicide during (early) pregnancy or puerperium.
2. Provide guidance on the minimal acceptable evidence of early pregnancy in the absence of objective clinical evidence (e.g. a pregnancy test) and specify on the use of information obtained through verbal autopsy.
3. Specify where maternal deaths of citizens who die outside of their country of residence should be counted to ensure that all maternal deaths globally are counted.
4. Discuss the relevance of classification in direct or indirect causes and the addition of classification in multimorbidity categories.
5. Provide guidance on selecting the underlying causes when concurrent comorbid direct and indirect conditions exist, or multiple direct complications co-occur.

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Supplementary file 1. Case description pregnancy-related deaths classified as "no maternal death" by all three MDR committees

Case	Gestational age	Description
Pregnancy test negative		
1	Last menstruation 4 weeks ago	Pain in the belly, severe anaemia, pregnancy test negative
2	According to husband pregnant	Pain in the belly, pregnancy test negative, human chorionic gonadotrophins (HCG) < 1
Coincidental deaths		
3	24 weeks	Haemorrhagic shock following impact trauma
4	25 weeks	Trauma capitis and pneumo-sepsis
Late maternal deaths		
5	8 weeks postpartum	Tachypnoea, diarrhoea, vomiting
6	9 weeks after caesarean	Diarrhoea, fever, vomiting, acute respiratory distress
7	10 weeks postpartum	Pre-eclampsia. Developed meningitis/encephalitis
8	11 weeks postpartum	Breast cancer
9	11 weeks postpartum	Cervical cancer
10	12 weeks postpartum	Peripartum cardiomyopathy
11	16 weeks after early pregnancy	Probably early pregnancy (human chorionic gonadotrophins (HCG) 181), after 16 weeks pulmonary embolus, autopsy showed no pregnancy
12	16 weeks after caesarean	Pregnancy complicated by pre-eclampsia. Died at home suddenly
13	19 weeks postpartum	Oesophageal cancer
14	24 weeks postpartum	Delivered premature (at 35 weeks), lupus erythematosus and sickle cell anaemia.
15	24 weeks postpartum	Peripartum cardiomyopathy
16	41 weeks post caesarean	Laparotomy due to ileus, many adhesions

Supplementary file 2. Case description of the 2010-2014 maternal deaths of Suriname classified as "unspecified"

	Gestation	Case description	Classification by MDR Committees		
			Suriname	Jamaica	Netherlands
1	9 months pregnant	Came from the interior, died in the car and was immediately transferred to the mortuary.	Unspecified	Unspecified	Unspecified
2	23 weeks according to family	Died at home in the interior. Complained of headache and dizziness 3 months before.	Unspecified	Unspecified	Unspecified
3	Verbal autopsy: early pregnancy	Died at home from unknown cause. Verbal autopsy with family: early pregnancy. Examination: no fundal height palpable, but peripheral oedema of both feet.	Unspecified	Unspecified	No Maternal death
4	35 days postpartum	Uncomplicated childbirth. Died at home 35 days later. No further information available.	No Maternal death	Unspecified	Unspecified
5	3 days postpartum	Uncomplicated childbirth. Died 3 days later with pain in legs and belly. No further information available.	Other Direct causes	Unspecified	Other Direct causes
6	Early pregnancy	Died before reaching hospital. Had abdominal pain, vaginal blood loss and chest pain. Verbal autopsy with family: could be pregnant	No Maternal death	Direct	Unspecified
7	25 weeks	Severe hypertension and severe dyspnoea followed by respiratory arrest	Direct	Direct	Unspecified
8	35 weeks	Grande multiparous, breech delivery in interior, retained placenta, died during transport to city. Blood loss not recorded.	Direct	Direct	Unspecified

Supplementary file 2. Continued

	Gestation	Case description	Classification by MDR Committees		
			Suriname	Jamaica	Netherlands
9	37 weeks	Obstructed labour, died in interior 3 hours after full dilation and ruptured membranes.	Direct	Direct	Unspecified
10	1 week postpartum	Two previous caesareans. Delivery of dead child at 27 weeks, curettage postpartum. One week later died at ER with normal vitals, normal laboratory results.	Direct	Direct	Unspecified
11	5 hours after caesarean	Caesarean for foetal distress at 41 weeks, stillbirth born. Post-caesarean hypotensive and found dead an hour later.	Direct	Direct	Unspecified
12	40 weeks	Died suddenly during delivery after rupture of membranes.	Direct	Direct	Unspecified
13	+/- 27 weeks	Found in vomit, unconscious with fever and high pulse and died. Abnormal kidney and liver enzymes.	Direct	Indirect	Unspecified
14	35 weeks	Atypical pneumonia, respiratory insufficiency and died after one week.	Indirect	Indirect	Unspecified
15	2 weeks postpartum	AIDS with heart failure and sepsis. No medical file available.	Indirect	Indirect	Unspecified
16	+/- 30 weeks	Known with an unknown illness before pregnancy. Vomits and probably had an exacerbation of disease. Did not seek medical help and died in interior.	Indirect	Indirect	Unspecified

Supplementary file 3. Sensitivity analysis for agreement among MDR committees in type of maternal death and ICD-MM underlying causes, expressed in Kappa (95% CI)

Type of maternal death			
	Overall	**Suriname - Jamaica**	**Suriname - the Netherlands**
All files (n=73)	0.53 (0.44-0.62)	0.69 (0.53-0.86)	0.48 (0.32-0.63)
Only cases with consensus on classification as maternal death (n= 62)	0.61 (0.49-0.72)	0.80 (0.58-1.0)	0.52 (0.33-0.72)
Complete files only (n=53)	0.69 (0.58-0.79)	0.80 (0.60-0.99)	0.64 (0.46-0.82)
WHO ICD-MM group of underlying causes			
	Overall	**Suriname - Jamaica**	**Suriname - the Netherlands**
All files (n=73)	0.52 (0.47–0.58)	0.63 (0.53–0.73)	0.49 (0.39–0.59)
Only cases with consensus on classification as maternal death (n= 62)	0.58 (0.52–0.65)	0.69 (0.57–0.81)	0.54 (0.43–0.66)
Complete files only (n=53)	0.58 (0.51-0.65)	0.66 (0.54-0.78)	0.53 (0.42-0.64)

Supplementary file 4. Case description of the 2010-2014 maternal deaths of Suriname classified as "other direct obstetric causes"

Case	Gestation	Case description	Classification by MDR Committees		
			Suriname	Jamaica	Netherlands
1	39 weeks	Collapsed during delivery, amniotic fluid embolism	Other Direct Causes	Other Direct Causes	Other Direct Causes
2	41weeks	Collapsed during delivery, amniotic fluid embolism	Other Direct Causes	Other Direct Causes	Other Direct Causes
3	24 weeks	Suicide by autointoxication	Other Direct Causes	Other Direct Causes	Other Direct Causes
4	0 days postpartum	Hypertension, abruption complicated by massive blood loss after childbirth.	Other Direct Causes	Hypertensive	Haemorrhage
5	30 days postpartum	Pre-eclampsia complicated by intra-cranial cerebral bleeding postpartum.	Other Direct Causes	Hypertensive	Other Direct Causes
6	27 weeks	Home delivery stillbirth. Normotensive with headache and vomiting. Died one week later.	Other Direct Causes	Hypertensive	Unspecified
7	3 days postpartum	Lupus and hypertension with thrombocytopenia complicated by massive blood loss.	Other Direct Causes	Haemorrhage	Haemorrhage
8	0 days postpartum	Hypertension and abruption placentae. Uterine torsion, hysterec-tomy and massive bleeding.	Other Direct Causes	Haemorrhage	Hypertensive
9	37 weeks	Obstructed labour, died in interior 3 hours after full dilation and ruptured membranes.	Other Direct Causes	Haemorrhage	Unspecified
10	11 days postpartum	Severe pre-eclampsia, stillbirth of one of twins, caesarean section, followed by severe hematemesis, coagulation disorder and respiratory insufficiency.	Other Direct Causes	Indirect	Indirect

Supplementary file 4. Continued

Case	Gestation	Case description	Classification by MDR Committees		
			Suriname	Jamaica	Netherlands
11	41 days postpartum	Pulmonary hypertension with respiratory insufficiency six weeks after childbirth. No pulmonary embolism.	Other Direct Causes	Indirect	Indirect
12	40 weeks	Died instantly during labour when the membranes ruptured	Other Direct Causes	Other Direct Causes	Unspecified
13	0 days postpartum	Found dead in her bed five hours after caesarean section	Other Direct Causes	Other Direct Causes	Unspecified
14	34 weeks	Immune thrombocytopenic purpura. Pulmonary bleeding and respiratory insufficiency.	Indirect	Other Direct Causes	Indirect
15	Early pregnancy	Suicide by autointoxication	No maternal death	Other Direct Causes	Other Direct Causes
16	Early pregnancy	Suicide by autointoxication	No maternal death	Other Direct Causes	No maternal
17	10 weeks	Suicide by autointoxication	No maternal death	Other Direct Causes	Indirect
18	1 day postpartum	Caesarean section complicated by respiratory insufficiency, history of severe mitral valve stenosis	Indirect	Indirect	Other Direct Causes
19	0 days postpartum	Severe pre-eclampsia, pulmonary oedema, eclampsia, cardiac arrest	Hypertensive	Hypertensive	Other Direct Causes
20	0 days postpartum	Hypovolemic shock due to uterus rupture	Haemorrhage	Haemorrhage	Other Direct Causes
21	Early pregnancy	Died before hospital admission. Abortion, chest pain and dyspnoea. Curettage pathology: no evidence of pregnancy.	No maternal death	No maternal death	Other Direct Causes

The golden hour of sepsis: an in-depth analysis of sepsis-related maternal mortality in middle income country Suriname

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ABSTRACT

Background: Sepsis was the main cause of maternal mortality in Suriname, a middle income country. Objective of this study was to perform a qualitative analysis of the clinical and management aspects of sepsis-related maternal deaths with a focus on the 'golden hour' principle of antibiotic therapy.

Methods: A nationwide reproductive age mortality survey was performed from 2010 to 2014 to identify and audit all maternal deaths in Suriname. All sepsis-related deaths were reviewed by a local expert committee to assess socio-demographic characteristics, clinical aspects and substandard care.

Results: Of all 65 maternal deaths in Suriname 29 (45%) were sepsis-related. These women were most often of low socio-economic class (n=23, 82%), of Maroon ethnicity (n=14, 48%) and most deaths occurred postpartum (n=21, 72%). The causes of sepsis were pneumonia (n=14, 48%), wound infections (n=3, 10%) and endometritis (n=3, 10%). Bacterial growth was detected in 10 (50%) of the 20 available blood cultures. None of the women with sepsis as underlying cause of death received antibiotic treatment within the first hour, although most women fulfilled the diagnostic criteria of sepsis upon admission. In 27 (93%) of the 29 women from which sufficient information was available, substandard care factors were identified: delay in monitoring in 16 (59%) women, in diagnosis in 17 (63%) and in treatment in 21 (78%).

Conclusion: In Suriname, a middle income country, maternal mortality could be reduced by improving early recognition and timely diagnosis of sepsis, vital signs monitoring and immediate antibiotic infusion (within the golden hour).

BACKGROUND

Sepsis is a major cause of severe maternal morbidity and mortality, especially in low- and middle- income countries. Early recognition of sepsis is crucial and sepsis should be treated by resuscitation with fluids and effective intravenous antibiotics should be given within one hour of the diagnosis.[1] The "golden hour of sepsis" stresses the relationship between timely initiation of antibiotic treatment and outcome: each hour delay in treatment reduces sepsis survival by 7.6%.[2] Pregnancy and delivery predispose women to infectious complications due to immunological and physiological alterations or from tissue damage during delivery. Recognition of sepsis during pregnancy, delivery and postpartum is difficult because of physiological adaptations to pregnancy, blood loss and increased maternal activity during labour.[3] WHO recently launched a new consensus defining maternal sepsis: a life-threatening condition defined as organ dysfunction resulting from infection during pregnancy, childbirth, post-abortion, or postpartum period.[4]

Although the 'golden hour of sepsis' principle is not validated for women with pregnancy or in the puerperium due to a lack of studies, the principle is assumedly even more important in pregnant, predisposed women where recognition is more difficult. Globally, maternal sepsis (10%) is the third most frequent cause of direct maternal deaths, preceded by haemorrhage (27%) and hypertension (14%).[5-7] In low- and middle income countries (LMIC) maternal sepsis is a larger contributor to maternal mortality than in high- income countries (10.7% vs. 4.7% respectively).[5,8] In high-income countries, however, maternal morbidity and mortality due to sepsis is increasing.[9,10]

Suriname is an upper middle income country in South America with a maternal mortality ratio of approximately 130 per 100.000 live births between 2010 and 2014.[11] A confidential enquiry in Suriname in 1991 reported sepsis to be the third most frequent underlying cause of maternal death (n=10/64, 16%).[12] We recently published an increase in maternal deaths from sepsis, with sepsis as the most frequent cause (n=17/65, 27%).[11] This is poorly understood; therefore, an in-depth case analysis was considered necessary.

Classification of maternal deaths into direct (obstetric) and indirect (non-obstetric) causes has given the impression that direct maternal deaths should receive greater attention than indirect deaths. However, since the focus is on the reduction of all preventable deaths, division between direct and indirect maternal deaths can be seen as arbitrary and counterproductive.[13] In this study, we therefore choose for a more theme-based approach by analysis of all sepsis-related deaths.

Primary objective of this study was to perform a qualitative analysis of the clinical aspects and management (based on the golden hour principle) of sepsis-related maternal deaths in Suriname. Secondary objectives were first to describe incidence and characteristics, second to analyse underlying causes, and third to evaluate quality of care and finally substandard care identification with audit to improve sepsis prevention, recognition and treatment strategies.

METHODS

Suriname is multi-ethnical with 541.638 inhabitants and one of the smallest populated countries in South America, with a density of 3,3 inhabitants per square kilometre. There are approximately 10.000 deliveries annually of which most in hospitals led by midwives and obstetricians (82%).[11] Women with high-risk pregnancies are referred by the primary health services, which can take more than two hours, as some rural areas are only accessible by boat or airplane. Postpartum, women are usually discharged from hospital six hours after an uncomplicated delivery. They are seen at outpatient clinics or hospitals once, seven days after discharge. Postnatal care home visits are not done.

In 2015 a reproductive age mortality survey (RAMoS) was performed to identify maternal deaths in Suriname between 2010 and 2014.[11] Medical records were collected of pregnancy related deaths identified by vital registration, or by screening of medical archives of all hospitals and primary care facilities. An anonymous case summary was made conform the FIGO-LOGIC *MDR clinical summary form* tool.[14] A local expert committee consisting of obstetricians,

midwives, internal medicine specialists or anaesthetists reviewed each case summary. The committee agreed on the underlying causes and classified the cases.[11] To analyse substandard care factors an adapted version of the FIGO-LOGIC MDR *Grid analysis of clinical case management* form was used.[14] For this study specifically, medical records of all maternal deaths related to sepsis, were scrutinised for signs of sepsis, clinical management, primary sources of infection and causative pathogens. Data were manually entered into IBM SPSS version 21.0 (Armonk, New York, USA) for analysis. Descriptive statistics and frequencies were used to describe patient demographics, clinical and pregnancy characteristics and substandard care factors. Graphs were manually made in IBM SPSS version 21.0 and Microsoft Excel 2016 to demonstrate qualitative information on sepsis diagnosis and management.

Definitions: Sepsis-related maternal deaths included deaths with sepsis as the underlying cause, sepsis as the mode of death and sepsis as a contributing factor. The underlying death cause was defined as the disease or condition that initiated the chain of events leading to death.[15] The mode of death was the disease or condition ultimately leading to death.[15] A contributing factor was defined as a condition existing before or developed during the chain of events leading to death, that predisposed the woman to death but was not causing death.[15]

Clinical diagnosis of severe maternal sepsis was made by using the UK Obstetric Surveillance System definition, which is an adapted version of the systemic inflammatory response syndrome (SIRS) criteria: an assumed or proved infection with at least two of the four criteria (temperature of > 38 ℃ or < 36 ℃, heart rate of > 100 beats per minute, respiratory rate of > 20 per minute, white blood cell count of > 17 x 10^9 cells/L or < 4 x 10^9 cells/L) measured on two occasions at least four hours apart.[9,10] Severe sepsis was associated with organ dysfunction (i.e. cardiovascular, respiratory, renal, coagulation, hepatic, neurological and uterine), hypoperfusion or hypotension.[16,17] Organ dysfunction was determined with the WHO near-miss tool.[18] In depth analysis of the maternal deaths with sepsis as underlying cause was performed in this study by determining when the first

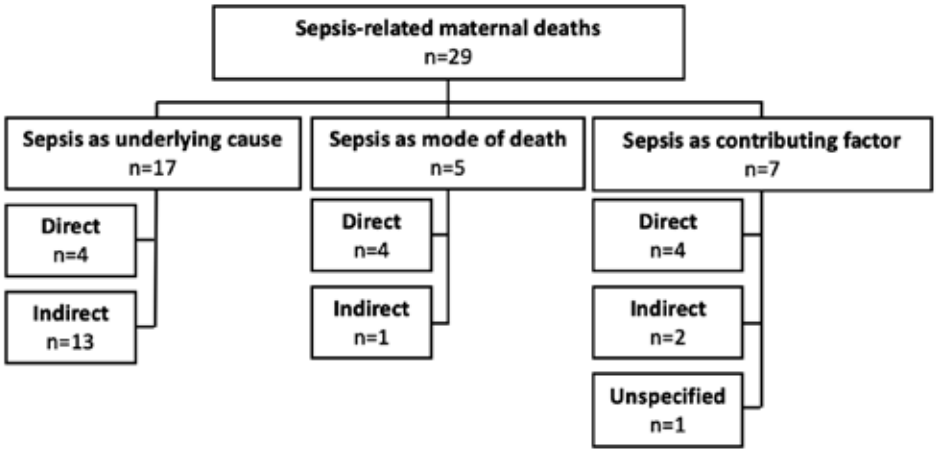
clinical signs of sepsis were manifested. The 'golden hour' principle (intravenous antibiotics given within an hour of severe sepsis diagnosis) was then evaluated.[1] Substandard care was defined as care below expected standards in the specific setting the woman was treated. The local expert committee evaluated substandard care in the absence of guidelines on sepsis in Suriname. Assessment of delay in receiving care was made by evaluating vital signs monitoring, diagnosing sepsis and initiation of antibiotic treatment. Other sub- standard care factors such as miscommunication, availability and patient-associated factors were also evaluated.

Ethical considerations: The medical ethical review board of the Surinamese Central Committee on Research Involving Human Subjects and the Ministry of Health of Suriname approved the study [VG 006–15]. Patient's names, hospitals and health care workers information remained confidential. No informed consent was required as only retrospective anonymised information from medical records of deceased women was used.

RESULTS

In the previously reported study on maternal mortality in Suriname between 2010 and 2014 sepsis was the most frequent underlying cause of death occurring in 17 of the 65 maternal deaths.[11] Of the women who died of other underlying causes, in five sepsis was the mode of death and in seven women sepsis was contributing to the death. Hence, in total 29 (45%) of the 65 maternal deaths were sepsis-related (figure 1). Medical records of two sepsis-related deaths (classified as indirect deaths with sepsis as underlying cause) were missing, therefore in-depth analysis of clinical aspects and substandard care was performed in 27 (93%) of sepsis-related maternal deaths. All the sepsis-related cases defined by the expert committee were also diagnosed by the clinicians who were in charge of the patients.

Figure 1. Overview of the sepsis-related maternal deaths in Suriname, 2010-14



Characteristics: In fourteen (48%) of the twenty-nine sepsis-related maternal deaths women were from maroon ethnicity, of which 13 (93%) had social insurance (insurance paid by the government for people of low socio-economic status) (table 1). Death occurred postpartum in 21 women (72%), mostly within one week (n=13, 62%). Two of the HIV-positive deceased women also had sickle cell (type SS) disease. Eighteen women (62%) died in the intensive care or coronary care unit, while nine (31%) died on the ward where critically ill women could not be monitored adequately. One woman died in the emergency department and one at home. Caesarean section was performed in eight (38%) of the 21 postpartum, sepsis-related deaths. All were elective caesarean sections; in two of these eight women the death was classified as a direct maternal death (table 2). In four women a caesarean section was performed because of pre- eclampsia, in one case because of foetal distress, one woman had a sickle cell crisis, and two women were in a critical condition due to heart failure and Shigella sepsis.

Sepsis as the underlying cause: Four women with sepsis as underlying cause were classified as direct maternal deaths (table 2). Underlying causes were endometritis in three women and wound infection in one woman.

Table 1. Characteristics of the sepsis-related maternal deaths (n=29)

	n=29 (100%)
Age	
< 20	7 (24)
20-35	18 (62)
> 35	4 (14)
Ethnicity	
Hindu	5 (17)
Creole	6 (21)
Maroon	14 (48)
Javanese	3 (10)
Indigenous	0 (0)
Mixed	1 (4)
Insurance (n=28)	
Social insurance	23 (82)
State health	4 (14)
Private	1 (4)
Not insured	0 (0)
Parity (n=27)	
< 3	18 (67)
≥ 3	9 (33)
Antenatal care[1] (n=23)	
None	4 (19)
< 4	6 (29)
≥ 4	11(52)
Sickle cell disease (n=19)	
SS	4 (21)
Negative	15 (79)
HIV (n=23)	
Positive	6 (26)
Negative	17 (74)
Anaemia in mmol/L (n=23)	
Severe anaemia (Hb ≤ 4.5)	6 (26)
Moderate anaemia (Hb 4.6 – 6.5)	8 (35)
Mode of delivery (n=21)	
Spontaneous	13 (62)
Caesarean section	8 (38)
Twins (n=23)	
Yes	3 (13)
No	20 (87)

Table 1. continued

	n=29 (100%)
Stillbirth[2] (n=27)	
Yes	13 (48)
No	14 (52)
ICU-admission	
Yes	18 (62)
No	11 (38)
Gestation at death	
Early pregnancy	2 (7)
Antepartum (n=6)	
< 34 weeks	*4 (14)*
≥ 34 weeks	*1 (3)*
GA unknown	*1(3)*
Postpartum (n=21)	
≤ 48 hours	*4 (14)*
2 – 7 days	*9 (31)*
1 – 6 weeks	*8 (28)*

Legend [1] Antenatal care starting from gestation of 16 weeks; [2] Stillbirth of a gestation of more than 22 weeks or 500 grams.

All women had term or near-term pregnancies and died within the first week postpartum. They had ruptured membranes less than 12 hours before delivery and none of the neonates died or showed signs of infection. The remaining 13 deaths were classified as indirect maternal deaths: pneumonia (n=7, 54%), meningitis (n=2), gastro-enteritis (n=2), urosepsis (n=1) and HIV therapy-induced hepatitis (n=1).

Sepsis as the mode of death: These five cases included death from 1) a bowel perforation following a mechanically induced abortion; 2) a central venous line sepsis in a woman in the ICU with bleeding from coagulation disorders following foetal death syndrome; 3) a craniotomy wound infection in a hypertensive woman with intracranial bleeding and eclampsia; 4) severe sepsis following multi-organ failure after iatrogenic hypotension due to overdose of antihypertensive medication in severe pre-eclampsia and; 5) endocarditis in a woman with aortic valve prosthesis.

Table 2. Case description of direct maternal deaths with sepsis as underlying cause

Case	Diagnosis	Culture	Time Death	Time to death	ICU	Antibiotics
Teenager Term pregnancy	Endometritis after manual placenta removal	Not performed	PP 3 days	3 days	No	Amoxicillin orally
40+ years Near term pregnancy	Caesarean due to pre-eclampsia, complicated by endometritis and pneumonia	Blood culture: no growth	PP 6 days	7 days	Yes	Initially amoxicillin orally. After 2 days intravenous amoxicillin, gentamycin and metronidazole
Term pregnancy HIV +	Vacuum extraction and episiotomy complicated by endometritis and pneumonia	Blood culture: P. aeruginosa (no suscep-tibility done)	PP 7 days	2 days	No	Initially ciprofloxacine orally profylactic. 5 days later intravenous cefotaxime, metro-nidazole, cotrimoxazole
Near term pregnancy HIV + HbSS	Caesarean due to pre-eclampsia, complicated by a wound infection	Blood culture: no growth	PP 7 days	2 days	Yes	Initially amoxicillin orally. After 5 days amoxicillin intravenously + metro-nidazole, gentamycin and ciprofloxacine

Sepsis as a contributing factor

In seven cases sepsis was a contributing factor; underlying causes were severe pre-eclampsia and/or eclampsia (n=4), diabetic kidney failure with an infected diabetic foot and osteomyelitis (n=1), heart failure in a woman with mitral valve prostheses and endocarditis (n=1) and one case where sepsis contributed to the death but with the cause remaining unclear. The main cause of infection was pneumonia, which affected 14 women (48%), followed by wound infections (n=3, 10%) and endometritis (n=3, 10%). Blood, urine and/or sputum cultures or vaginal swabs were obtained in 23 cases (85%).

Table 3. Micro-organisms isolated from the cultures performed

Blood cultures n=10/20 (50%)	**Urine cultures** n=3/13 (23%)	**Sputum cultures** n=4/6 (66%)
P. aeruginosa[n=2]	Actinobacter	P. aeruginosa [n=2]
Enterobacter [n=2]	K. pneumoniae	K. pneumoniae [n=2]
Gram negative rods [n=2]	E. Coli	
E. Coli		
Shigella flexneri		
β-hemolytic strept.group A		
Enterococcus faecalis		

No culture was done in four cases because of temperature below 38 degrees (n=2), very rapid deterioration of the condition of the patient (n=1) and loss of blood sample before reaching the laboratory (n=1). Results of the cultures were available in 20 cases and not traceable in the remaining three cases. Either one of the cultures were positive in 15 cases (75%). Blood culture showed growth of pathogens in 10 cases (50%) (table 3).

Clinical aspects: Figure 2 demonstrates the number of cases per dysfunction organ system. At least two organ dysfunctions were present in 20 (74%) cases. The respiratory system was the most frequently documented organ dysfunction in 17 cases (63%), followed by the renal (n=14, 52%) and hepatic system (n=12, 44%).
Substandard care factors which contributed to death were identified in 25 of 27 women (93%) with a sepsis related death. Two medical files were not reviewed for substandard care as they were missing. Delay in reaching care occurred in four women (15%), while delay in receiving care in the hospital occurred in 24 women (89%) (table 4).

Delay in monitoring & diagnosis: The expert committee identified delay in the diagnosis of sepsis in 17 women (63%). Inadequate monitoring occurred in 16 women (59%). In Figure 3 the adapted SIRS-criteria that were used and reported by clinicians in the 27 cases are shown. Respiratory rate was the most poorly reported vital sign, reported in only 13 women (52%).

Figure 2. Sepsis-related maternal deaths with organ dysfunction (n=27)

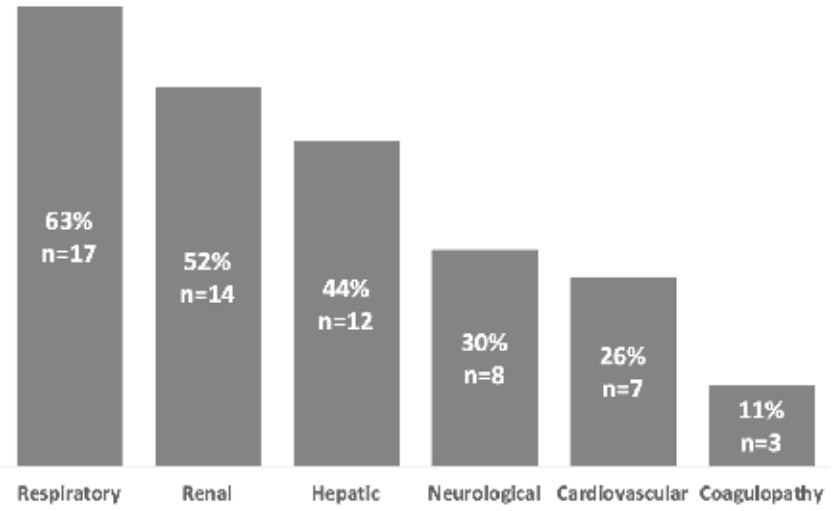
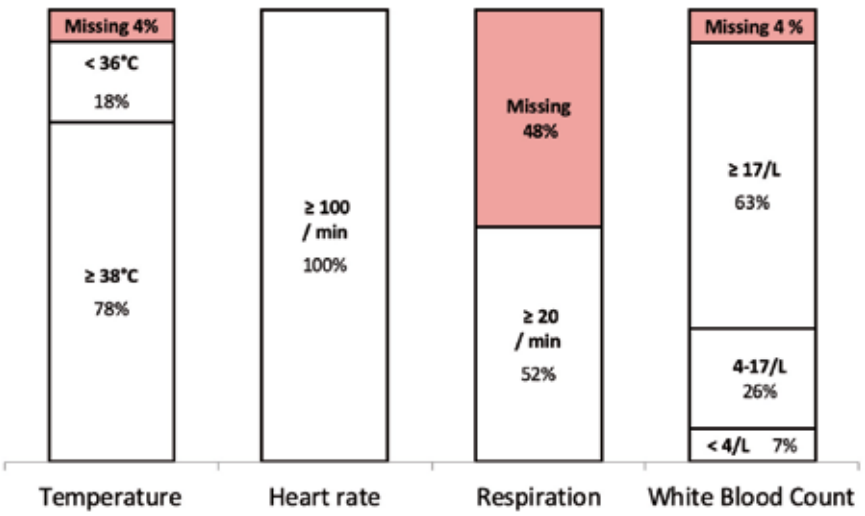


Figure 3. Clinical signs when sepsis was diagnosed in the sepsis-related maternal deaths in Suriname between 2010 and 2014 (n=27)



Temperature was below 36 degrees in five women (18%) and white blood cell count was normal in seven women (26%). Information on mental state was missing in 19 women (70%). In-depth analysis of the maternal deaths with sepsis as the underlying cause (n=17) is provided in Figure 4. Vital signs were taken upon admission in all cases, though any of the vital signs were rechecked within 24 hours in only seven septic women. According to documentation temperature, pulse and blood pressure were rechecked within 24 hours in respectively four (24%), five (30%), and six (35%) women. Organ dysfunction was already present when initial signs of sepsis were manifest in 15 of the 17 women. In two women no information was available because no laboratory tests were done at the time sepsis was diagnosed.

Delay in treatment and the golden hour principle: The committee agreed that there was delay in treatment in 22 women (81%). Intravenous antibiotic treatment was given in 25 of the 27 women (93%). In 12 women (44%) empiric antibiotic treatment appeared to be right according to the culture sensitivity profiles. In eight women (30%) frequent switch in antibiotics, with more than three different regimes, was given within three days, without sensitivity profiles known. In-depth analysis of the maternal deaths with sepsis as the underlying cause (n=17) illustrated that 15 women (88%) had already signs of severe sepsis when admitted in the hospital. In none of those women antibiotics were administered within the first hour of diagnosis of sepsis (Figure 4). Mean (SD) time between the first sign of sepsis and initiation of intravenous antibiotic treatment was 12.5 hours (SD 5, range 2–48 hours). In five (29%) women intravenous antibiotics were administered more than 24 hours after the onset of sepsis. No intravenous antibiotics were administered in two women: in one case the woman died within two hours after the diagnosis and in the other woman antibiotics were given orally.

Other substandard care factors: Delay due to miscommunication between health care professionals occurred in ten cases (37%) (table 4). An example where miscommunication occurred is the case of direct maternal death from sepsis after

manual placenta removal: one gynaecologist prescribed primperan (a gastrointestinal stimulant) for vomiting in this woman with a bumped and shiny belly and another stopped it the next day considering primperan to be contra-indicated when an intestinal obstruction is suspected. In three cases (11%) an Intensive Care bed was requested but not available. In one case (4%) blood was not available for transfusion. The expert committee agreed that substandard care factors definitely or most probably led to death in 10 of the 27 women (37%).

Discussion

This is the first detailed clinical study of pregnant and postpartum women dying of sepsis in Suriname. Of all 65 maternal deaths from 2010–2014 in Suriname 29 (45%) were sepsis related and in 17 of these women (27%) sepsis was the leading underlying cause of death. The attribution of sepsis to maternal deaths in Suriname was much higher than the 8.3% reported in Latin America and Caribbean or the 10.7% worldwide.[5] In Brazil, however, infection was responsible for nearly half (46%) of all facility-based maternal deaths, much higher than previously thought.[19] While various high-income countries performed extensive qualitative studies on sepsis-related maternal mortality and morbidity, there is scarce data from middle- or low- income countries.[9,10,19-22] Three major findings of our study were identified: first, most sepsis-related maternal deaths occurred in women with low economic status and postpartum, within one week after delivery; second, the most common identified source of sepsis causing maternal deaths in Suriname was pneumonia; and finally, there was a major delay in monitoring, diagnosis and prompt treatment with regards to the golden hour principle. Classifying the cause of maternal death is a complex matter with great classification differences between countries.[23] WHO guideline for ICD-MM classification states that the underlying cause of maternal death is where the chain of events leading to death starts. The ICD-MM classification system, however, impedes for example “a death with an abortive outcome” to be classified as a “pregnancy-related infection”.

Table 4. Substandard care of sepsis-related maternal deaths (n=27)

	n=27 (100%)
Delay in reaching care	4 (15)
Delay in receiving care	24 (89)
Health care provider factors	
Insufficient quality of care	21 (77)
Inadequate monitoring	16 (59)
Poor Communication	10 (37)
Delay in diagnosis	17 (63)
Delay in treatment	21 (78)
Unavailability	
Intensive Care Unit Bed	3 (11)
Staff	2 (7)
Medication	4 (15)
Blood	1 (4)
Patient factor	
Poor adherence to medication	7 (26)
Substandard factors leading directly to maternal death	
Definitely / most probably	10 (37)
Possibly	13 (48)
Unable to determine	2 (7)

Also, a woman can only have one underlying cause of death for classification purposes. One of the cases in our study, a woman who died due to com- plications (sepsis) of a mechanically-induced abortion, was classified as "a death with an abortive outcome", would not be included in this study if only underlying causes were studied. Similarly, another case of a woman with cerebral bleeding due to hypertensive disorder who died due to a sepsis caused by the craniotomy wound, would not have been included (sepsis as mode of death).

While malaria in pregnancy caused maternal mortality in the nineties in Suriname (4,7%, n=3/64), no maternal deaths due to malaria have been diagnosed between 2010 and 2014.[11,12] This is in line with the numbers in the general population: deaths from malaria have declined with 92% since 1990.[24] Pneumonia was the most common source of sepsis in Suriname.

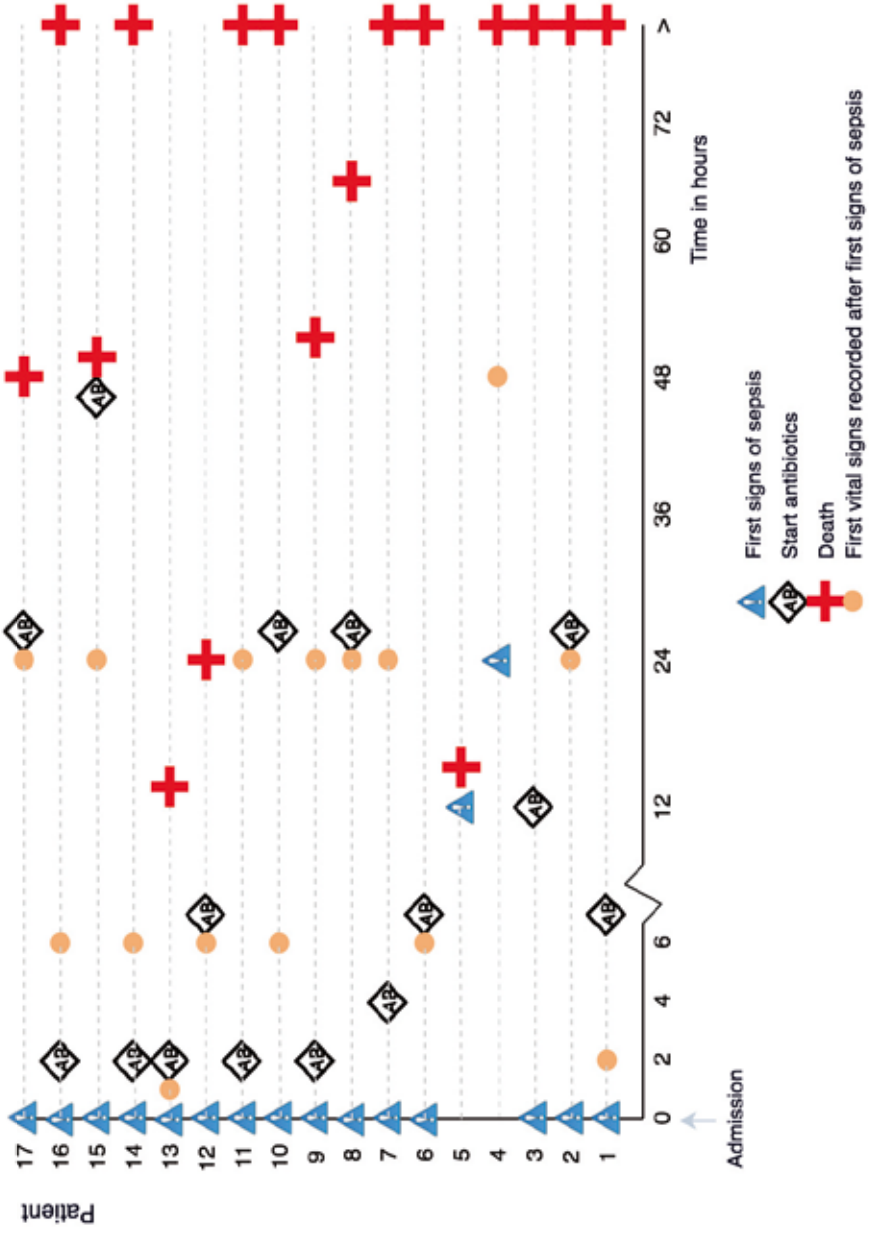


Figure 4. Overview of the time between admission, first signs of sepsis, first vital signs after admission, the initiation of antibiotic treatment and death per patient with sepsis as the underlying cause of death (n = 17)

Accordingly, as in the UK, not only genital tract sepsis but more importantly non-obstetric causes as especially pneumonia, but also urosepsis were reasons for maternal mortality.[22] The attribution of indirect causes has been increasing globally.[5] An improved enquiry and registration of deceased women on non-obstetric wards, as done in this study, can also be the result of the relative increase of indirect maternal deaths in middle income countries. Because a RAMoS was done nationwide, also indirect deaths at other wards than the maternity ward were included, leading to more non-obstetric cases as pneumonia.[11]

Delays in reaching health care facilities were not a major problem (n=4/27, 15%). Each year only 5% (n=500/10.000) of deliveries take place in the rural interior and these are mainly low risk pregnancies. However, delays in receiving quality care in health facilities occurred more frequently (n=24/27, 89%): there was delay in monitoring, diagnosis and treatment of sepsis- related deaths.[25] Suriname, with an MMR of 130, could be classified as stage III in the WHO model of "obstetric transition", which describes the shift of countries from high MMR to low ratios.[25] In this stage of transition indirect causes such as non-obstetric sepsis, are becoming important contributors to maternal deaths, whereas direct maternal deaths still remain significant. In this model essential recommendations to reduce maternal mortality for stage III include improvement of quality of intra-hospital care (third delay), with skilled birth attendance and appropriate management of complications.[25,26] Therefore, we focus on these delays in health facilities in greater detail.

Adequate monitoring of pregnant women for clinical signs of infection in early stages is crucial.[27,28] To identify critically ill pregnant women a modified early obstetric warning score (MEOWS) could be used.[29] To perform MEOWS systolic blood pressure, diastolic blood pressure, respiration rate, heart rate, oxygen saturation, temperature and conscience level should be assessed repeatedly. Recognition of predetermined abnormal values of these vital signs should lead to an adequate medical response.[29]

In this study substandard care by poor monitoring occurred in 16 of 27 women (59%) and there had been inadequate recognition of early warning signs. No

structural scoring of vital parameters as the MEOWS was used. In all sepsis-related cases initially there was a tachypnoea of >20 per minute (documented in 48% of the records) and/or a tachycardia of more than 100 per minute indicating first signs of severe sepsis.[20] However, these early signs of sepsis were not recognised in nine women (32%) as they died on the ward without receiving adequate monitoring and treatment.

Clinical characterization of sepsis may be achieved by performing a SOFA (sepsis-related or sequential organ failure assessment) score, which determines the extent of organ dysfunction.[30,31] Though SOFA is not validated in pregnant women, a simplified form of SOFA, the quick SOFA or qSOFA (respiration rate $\geq$22 per minute, altered mentation and systolic blood pressure <90 mmHg) can be used as a simple bedside test to identify women with suspected infection associated with poor outcome. Respiratory rate also seems to correlate with severity of sepsis.[27] In this study we did not use qSOFA as diagnostic or prognostic criterium as it is not validated in pregnant women. More importantly information on respiration rate (n=13, 48%) and mentation (n=19, 70%) were often missing in our population and it was therefore not possible to assess qSOFA scores.

This study illustrated that delay in monitoring led to delay in diagnosis and treatment of sepsis. Even when sepsis was recognised, in none of the cases antibiotic treatment was started within one hour. According to the Surviving Sepsis Campaign guidelines any sign of infection should promptly be recognised and treated.[1] Aggressive fluid resuscitation and early and appropriate antibiotic treatment is the best way to manage sepsis.[1,3] Antibiotic treatment should be started within one hour (golden hour principle).[1]

Recommendations to prevent maternal deaths from sepsis in Suriname

From this maternal death from sepsis analysis we could distillate three major recommendations for maternal care in Suriname:

1) improve postpartum care;

2) introduce a maternal sepsis bundle for diagnosis;

3) early treatment of pregnant and postpartum women in close collaboration with other medical disciplines;

4) improve postpartum care by improving the information given to patients and a structured care system after delivery;

5) introduction of standard recording of vital signs (as MEOWS) is strongly recommended in order to identify critically ill septic patients.[29]

Sepsis performance improvement programs which includes guidelines on monitoring, prevention and early treatment of sepsis are necessary.[1] Introduction, implementation and adherence to Surviving Sepsis Campaign (SSC) bundles (a set of recommendations for sepsis screening and treatment) could enhance the care for septic pregnant and postpartum women in hospitals. Selection of an optimal intra- venous empiric antimicrobial regimen is the cornerstone of the treatment of sepsis.[1] A nationwide guideline should be developed and implemented in Suriname. As non-obstetric causes of sepsis are becoming more important, a multidisciplinary approach in treatment of sepsis is essential.[1,22] Collaboration of obstetricians with other physicians as internal medicine specialists, microbiologists, nurses, and pharmacists is mandatory.

Strengths and limitations: Regarding the difficulties collecting clinical data from medical records in a middle income country, this extensive dataset is unique and valuable. There are, however, some limitations. Cases were analysed and classified by the expert committee based on information of medical records, in which documentation was not always sufficient and sometimes information was missing. However, the local team was accustomed to these records and scrutinised all medical information for signs of recognised medical comorbidities predisposing pregnant and postpartum women to infection including obesity, diabetes mellitus, HIV / AIDS, hepatitis, sickle cell disease, malaria, malnutrition, multiple gestations and severe anaemia.[1,21,32] Unfortunately, in this study information on weight and nutrition of the women was not available. At the moment we are prospectively collecting morbidity data for all pregnant women in Suriname. Finally, while WHO launched the new definition of maternal sepsis, it remains difficult to compare data

between countries because various criteria and definitions are used.[4] The WHO GLOSS, the Global Maternal Sepsis Study, in more than 500 healthcare facilities in 53 countries will address these issues.[4]

CONCLUSION

Sepsis was the leading cause of maternal death in Suriname, with most deaths occurring after delivery. Non-obstetric causes (as pneumonia) were the most important primary contributors to sepsis. Monitoring of critically ill septic patients was inadequate and antibiotics were not started within the "golden hour". A uniform international definition of sepsis in pregnancy / postpartum with clear criteria is mandatory for early recognition of sepsis. Close monitoring and prompt treatment of patients with sepsis is essential. Introduction of early sepsis warning signs, guidelines on postpartum care and introduction and implementation of SSC bundles for pregnant and postpartum women could prevent maternal deaths from sepsis.

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Bottom-up development of national obstetric guidelines in middle income country Suriname

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ABSTRACT

Background: Obstetric guidelines are useful to improve the quality of care. Availability of international guidelines has rapidly increased, however the contextualization to enhance feasibility of implementation in health facilities in low and middle income settings has barely been studied. This study describes the approach and lessons learned from the 'bottom-up' development process of context-tailored national obstetric guidelines in middle income country Suriname.

Methods: Local obstetric health care providers initiated the guideline development process in Suriname in August 2016 for two common obstetric conditions: hypertensive disorders of pregnancy (HDP) and post partum haemorrhage (PPH).

Results: The process consisted of six steps: (1) determination of how and why women died, (2) interviews and observations of local clinical practice, (3) review of international guidelines, (4) development of a primary set of guidelines, (5) initiation of a national discussion on the guidelines content and (6) establishment of the final guidelines based on consensus. Maternal enquiry of HDP- and PPH-related maternal deaths revealed substandard care in 90 and 95% of cases, respectively. An assessment of the management through interviews and labour observations identified gaps in quality of care and large discrepancies in the management of HDP and PPH between the hospitals. International recommendations were considered unfeasible and were inconsistent when compared to each other. Local health care providers and stakeholders convened to create national context- tailored guidelines based on adapted international recommendations. The guidelines were developed within four months and locally implemented.

Conclusion: Development of national context-tailored guidelines is achievable in a middle income country when using a 'bottom-up' approach that involves all obstetric health care providers and stakeholders in the earliest phase. We hope the

descriptive process of guideline development is helpful for other countries in need of nationwide guidelines.

BACKGROUND

Reducing maternal mortality remains a universal priority for clinicians, researchers and policymakers. The obstetric transition model describes five stages in which countries move, from high to low maternal mortality.[1] Phase three is considered a tipping point, in which pre- dominantly direct causes of mortality persist, but as most women reach hospitals, improving the quality of care (skilled birth attendance, appropriate management of complications) becomes essential to further reduce mortality.[1] In low- and middle income countries (LMIC), where informal sharing of knowledge and experience-based decision-making often dominates, the development and implementation of feasible clinical guidelines are key to improve quality of evidence-based, respectful maternity care.[2]

Evidence about guideline implementation strategies in low- and middle income countries has increased in the past years and a number of enablers of effective implementation have been identified.[3,4] The most import- ant known enabler is to use a multi-facetted strategy (i.e. combining different methods of implementation) instead of a single intervention (e.g. providing health care workers with existing guidelines).[3-7] Positive health care providers' attitude towards the guidelines is strongly associated with adherence to the guidelines. The process of guideline development before implementation is critical. By creating appropriate guidelines tailored to the context, use in local reality is ensured and sustainable adherence is created.[7-9]

Suriname is an example of a country in obstetric transition phase three with a fairly high maternal mortality ratio (MMR) of 130 per 100.000 live births compared to other countries in Central and South America.[10-12] Similar to most LMICs, the primary causes of maternal deaths in Suriname are postpartum haemorrhage (PPH) and hypertensive disorders of pregnancy (HDP).[11] The majority of these deaths are due to 'third delay' factors linked to the quality of care, such as in-hospital delay of diagnosis and treatment.[11,13] The introduction of nationwide guidelines for the

clinical management of these complications is therefore a promising strategy to improve health outcomes.

The aim of this article is to describe the approach and lessons learnt from our 'bottom-up' strategy to develop national guidelines tailored to the context of middle-in- come country Suriname for postpartum haemorrhage and hypertensive disorders of pregnancy. These lessons can inform and support the guideline development processes in other settings.

METHODS

Suriname is a middle income country on the northeastern coast of South-America with 550.000 inhabitants in 2016 and almost 10.000 deliveries annually. Of all deliveries, 92% of women give childbirth in the five hospitals in the country, while 8% deliver in primary health care centres and 2% at home. Four hospitals are located in capital city Paramaribo and one smaller hospital is located on the far West-coast, Nickerie.[14,15] In 2016, fifteen obstetricians, eight residents and approximately fifty midwives provided maternal care in the hospitals in Suriname. Obstetric care provision in Suriname is mainly influenced by Dutch guidelines (Nederlandse Vereniging van Obstetrie en Gynaecologie, NVOG) as residents follow two years of their training in the Netherlands.[16,17] In addition, the American College of Obstetrics and Gynecology (ACOG) and the World Health Organization (WHO) guidelines are used.[18-21] In 2015 and 2016 a national maternal death review committee was established, consisting of local obstetric health care providers. This committee audits all pregnancy-related deaths in the country. Among the recommendations are the implementation of national guidelines on the most important causes of maternal mortality and training emergency (obstetric) skills. Subsequently, the maternal death committee members initiated the bottom-up guideline development consisting of six-steps, as described below.

I. Determine how and why women died: A Reproductive Age Mortality Survey was initiated by a local obstetrician (LK) and the principle investigator (KV) to audit all maternal deaths between 2010 to 2014. The study revealed a maternal mortality

ratio of 130 per 100.000 live births with many preventable deaths due to post partum haemorrhage and hypertensive disorders.[11] The maternal deaths due to, or aggravated by HDP and PPH were further analyzed for substandard care factors and the three-delay model was applied to establish why women died and what could have prevented the death.[22]

II. Interviews and observations of local clinical practice: First, to determine the standard of care for HDP and PPH management, the obstetric departments of the five hospitals were asked to share their local protocols. Second, interviews on practice were performed with forty-three obstetric health care providers from all hospitals: 13 obstetricians, 8 residents, and 24 midwives. An anonymous national questionnaire was completed. The questionnaire was developed for the purpose of this study. The structure of the interview was based on international consensus on HDP and PPH prevention, diagnosis and treatment (adapted ACOG checklists).[19,23] Questions were also asked on encountered barriers and enablers in the current system. Semi-structured one-on-one interviews, conducted by the principle investigator (KV), were held with the gynaecologists and head of midwives of each hospital to assess their opinions and wishes with regard to the new guidelines.
Third, clinical observations were performed by four medical doctors working in the hospitals and four medical students conducting their rotations. The principle investigator provided the observers a summary of the abovementioned findings per hospital. During a two-month period (250 deliveries) observations were performed in all hospitals on whether the answers in the surveys matched reality. The medical students used the ACOG-adapted checklists for HDP and PPH during the observations.

III: Review international guidelines: The four international guidelines on HDP and PPH used most by local health care providers were compared for similarities and differences in definition, causes and recommendations in diagnosis and treatment. Both the HDP and PPH guidelines from the WHO, ACOG and NVOG were assessed. Additionally, the PPH guideline of the British Royal College of Obstetrics and

Gynaecology (RCOG) and HDP guideline of Australian Queensland Brisbane (QB) were assessed.

IV: Develop a primary set of guidelines: In August and September 2016 the initial version of the guidelines were drafted by four members of the study team and one nurse-midwife of each hospital. The above mentioned guidelines were used as a template. The drafted guidelines were reviewed by external (four international experts from the Netherlands) and internal reviewers (eighteen local obstetricians and nurse-midwives). The reviewers independently discussed the guidelines with the principle investigator. During a three-hour meeting with all the reviewers the 'key discussion points' were established and simulation-based trainings were prepared. A literature search was conducted on the 'key discussion points' by five of the authors (KV, TB, RP, LK, KB) for evidence-based answers and considerations.

V: Initiate national discussion about content of guidelines: Two hundred and one obstetric health care providers (obstetricians, paediatricians, anaesthesiologists, residents, doctors, midwives, nurses, trainees) and policy makers (Ministry of Health and Pan-American Health Organization (PAHO)) attended a four-day conference (November 10-13, 2016) to discuss the recommendations in two new national obstetric guidelines. The meeting was moderated by one local and one international obstetrician. The two guidelines were adapted during the conference. A two-hour simulation-based training was held on each day to practise and evaluate the content of the guidelines. These trainings were based on maternal deaths of the previous years and led by a team existing of one international expert, two local obstetricians, an anaesthesiologist and two midwives. The participants completed an evaluation survey (5-point Likert scale, from unsatisfied to extremely satisfied) about the different components of the conference.

VI: Final guideline development and evaluation

The last drafts of the guidelines were distributed digitally and on paper. All obstetric health care providers (including those who did not attend the meeting)

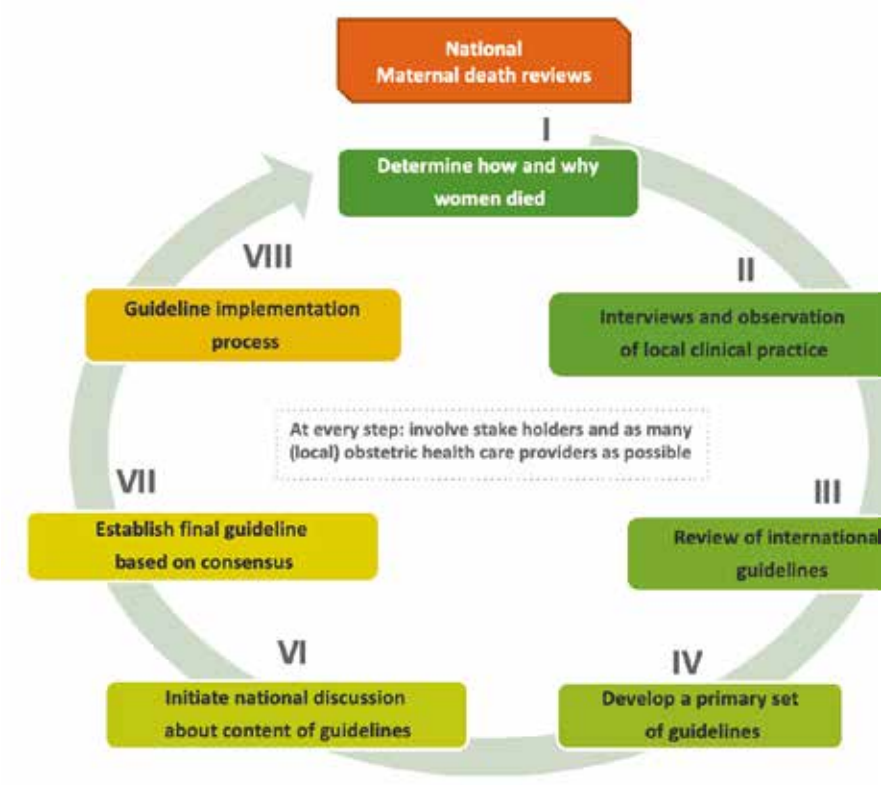
were requested to provide feedback within six weeks. The local obstetricians (n=13) and chief midwives of each hospital (n=5) were personally visited for the final feedback and their formal approval.

Ethical approval was obtained from the Surinamese Central Committee on Researching Human Subjects for the study of maternal deaths [Reference number VG 006-15] in March 2015.[11] The Surinamese Central Committee on Researching Human Subjects waived the need for approval for the remainder of the project.

RESULTS

The six phases of the guideline development process were executed in a period of four months (figure 1).

Figure 1. National obstetric guideline development strategy in Suriname



I: Determine how and why women died

The substandard care analysis of the extracted maternal deaths related to HDP (n=19) and PPH (n=21) in Suriname reveals that most substandard care factors are *third delay* factors due t a lack of quality of care (see table 1).[11]

The substandard quality in care seen in the maternal deaths was mostly due to the lack of anticipation, delay in recognition of seriously ill women, delay in providing available treatment and a lack of supportive treatment (e.g. oxygen, uterine massage). In three (15%) of the maternal deaths blood products were not available within 60 minutes. Medication (oxytocin, misoprostol or magnesium sulfate) was not available in two women who died of PPH during transportation to the hospital.

Table 1. Three-delay model of maternal deaths related to HDP and PPH

	HDP deaths n= 19 (%)	**PPH deaths n = 21 (%)**
1st delay (patients do not seek care)	1 (5.3)	1 (4.8)
2nd delay (patients do not reach care)	1 (5.3)	4 (19.0)
3rd delay (no adequate care in hospital), reasons:	17 (89.5)	20 (95.2)
i. Essential medications unavailable	-	2 (10.0)
ii. Blood products unavailable	N/A	3 (15.0)
iii. Necessary staff unavailable	1 (5.9)	2 (10.0)
iv. Lack of quality of care (significant delay in diagnosis and treatment, inadequate monitoring, poor supportive treatment)	16 (94.1)	19 (95.0)
Death most likely preventable	9 (47.4)	16 76.2)

II. Interviews and observations of local clinical practice: Two of the five hospitals used short local protocols for HDP and PPH. These protocols were available both digitally and on paper. The other three hospitals did not have protocols. Fourty-three interviews were conducted with obstetric health care providers and showed differences in perception of optimal HDP and PPH-care (table 2 and 3). The interviewees indicated that the guidelines most frequently used by local staff were from WHO, NVOG and ACOG, though only 60% (n=26/43) said to actually use them.[16-21] A frequently mentioned arguments of the health care providers was that

the international guidelines were *"complex, not applicable, not achievable, unclear and/or not practical in their use"*. Doctors mentioned that *"there are discrepancies between international guidelines leading to discrepancies in regimens between gynaecologists in daily practice"*. Lastly, midwives mentioned that they *"miss easy-to-use checklists or flowcharts which we can adapt to our situation"*. The 'standard care' regarding HDP and PPH per hospital can be found in supplementary file 1 and 2. Noteworthy, are differences in daily regimen between hospitals within five kilometers distance of each other.

Clinical observations revealed that the management of HDP and PPH was found to differ between obstetricians within the same hospital. We did not observe that the international guidelines were consulted by nurses or midwives in any of the hospitals. When asked for, the digitally available protocols could not be localised by the staff on duty in two of the hospitals. In PPH management, we observed blood loss estimation was often inadequately (text box 1).

Text box 1. Example of revelations during clinical labour observations

Blood loss measurement
Perception of staff
"Measurement of blood loss is very accurate as we always use a measuring cup" - explained by midwives and confirmed by obstetricians.

Reality
Delivery room: Blood loss measurement included only the blood clots (blood poured through a sieve, removing the plasma/fluids before pouring clots in a measuring cup) in 3 of 4 hospitals.
Operating theatre (caesarean): Blood loss measurement included only the blood loss by suction, in a measuring cup (not gauzes / clots) in 2 of 4 hospitals.

III: Review international guidelines: A summary of similarities and differences between the four international guidelines used most frequently by local health care providers is presented in supplementary file 3 and 4. The four HDP guidelines (WHO, ACOG, QB, NVOG) differed from each other in the following major recommendations: diagnosis of severe pre-eclampsia, timing of aspirin prevention, antihypertensive therapy choices and dose, magnesium sulfate dose and therapy duration, recommendations on fluid restriction, vital sign monitoring and timing

of delivery.[17,18,21,25] The four PPH guidelines (WHO, ACOG, RCOG, NVOG) differed from each other in the following major recommendations: active management in the third stage of labour (AMTSL), dose of uterotonics, oxygen therapy initiation, uterine massage, blood transfusion ratio, tranexamic acid, balloon tamponade, embolization, vessel ligation and hysterectomy.[16,19,20,24]

IV. Development of the two national guidelines: The first drafts of the guidelines were created in September 2016. International reviewers added specific recommendations, e.g. the use of tranexamic acid in PPH, the necessity of a blood transfusion protocol, restricting fluids in pre-eclampsia and aspirin prevention of pre-eclampsia. The local reviewers (all gynecologists and head nurses) requested for the guidelines to be more practical with flowcharts and checklists and with more specific recommendations, e.g. the frequency of vital sign monitoring in HDP or PPH. The 'key discussion points' were summarised and attached to the draft guidelines as an appendix.

V: Initiate national discussion about content of guidelines: The four-day meeting was attended by 201 health care providers, including all obstetricians (n=15), residents (n=4), the majority of midwives and nurses (-in training) (80%, n=161)) and different stakeholders, i.e. representatives of the Ministry of Health and the Pan-American Health Organization. Key discussion points were presented and discussed for final consensus on the HDP and PPH guideline (table 4 and 5). This discussions was facilitated by the local and international moderators who were prepared with evidence-based background information.

The simulation trainings in smaller groups were well-received as the local health care providers felt they *"could practice"* and felt *"safe to ask remaining questions".* The evaluation survey revealed that the majority (93%, n=186/201) of the health care providers were 'very satisfied' (4 or 5 points on scale of Likert) with the guideline development proces. There was a high rate of agreement on the content of the guidelines and commitment to implementation (82%, n=164/201).

Table 2. Interviews with obstetric health care providers on HDP care provision

	n = 43 (100%)
Definitions clear	
Pre-eclampsia	38 (88)
Severe pre-eclampsia	22 (51)
Eclampsia	34 (79)
Anticipation / prevention	
Risk factors known	36 (84)
Aspirine	10 (23)
Calcium	22 (51)
Oral medical treatment (1st line)	
1. Methyldopa	43 (100)
2. Hydralazine	43 (100)
3. Nifidipine (antepartum)	5 (12)
4. Labetalol	21 (48)
Parenteral medical treatment (2nd line)	
1. Hydralazine (direct shots)	43 (100)
2. Hydralazine (perfussor)	25 (58)
3. Labetalol	15 (35)
4. Ketanserin	5 (12)
Magnesium sulfate	
Loading dose (4-6 g/30 min)	26 (60)
Maintanance dose (1 g/hr)	43 (100)
Duration: 24 – 48 hours	43 (100)
Repeat (2 g/5 min) in seizure	6 (14)
Diazepam before $MgSO_4$	38 (88)
Stabilization of severe PE / eclampsia	
Minimum 48 hr before termination of pregnancy	8 (19)
Earliest termination in severe PE	
GA ≥27 weeks	23 (53)
GA ≥30 weeks	15 (35)
GA ≥32 weeks	5 (12)
Other	
Eclampsia box available [1]	9 (21)
Oxygen during eclampsia	12 (28)
Restrict fluids to < 2 L / 24 hrs	0 (0)
Early warning score (MEOWS)	7 (16)

Legend [1] Eclamspia kit includes magnesium sulfate, calciumgluconate, labetalol, hydralazin, sodium choloride ampoule, fluids (ringers lactate and sodium chloride), blood sample bottles, tourniquet, syringes, plaster to fix cannula, guedel aiways, bag and mask, oxygen, reflex hammer.

Table 3. Interviews with obstetric health care providers on PPH care provision

	n = 43 (100%)
Definitions clear	
PPH	38 (88)
Severe PPH	19 (44)
Clear when to alarm doctor	24 (56)
Anticipation / prevention	
Uterotonics in caesarean section	43 (100)
Uterotonics in all vaginal births	14 (33)
Controlled cord traction	19 (44)
Measuring blood	
Measuring by cup	18 (42)
Only clots measured	16 (37)
Medical treatment (1st line)	
Oxytocin i.m. or i.v. (2nd shot)	16 (37)
Oxytocin infusion (10IU/4 hrs)	43 (100)
Misoprostol 400mcg supp	41 (95)
Methergine 0.2mg i.m.	11 (26)
Resuscitation	
Always place 2nd i.v. line	11 (26)
Fluids: Crystalloids	43 (100)
Fluids: Colloids	16 (37)
Oxygen	20 (47)
Tranexamic acid (1 gr i.v.)	10 (23)
Blood transfusion	
Clear guidelines available	0 (0)
Indication: Hb <4 mmol/L	37 (86)
Indication: Hb <3.5 + Ht <0.20	6 (14)
Ratio: 1 PC : 2 FFP	9 (21)
Ratio: 2 PC : 1 FFP	34 (79)
Other	
PPH box available[1]	19 (44)
Balloon / B-Lynch / uterine pack	0 (0)
Hysterectomy if necessary	43 (100)
Early warning score (MEOWS)	9 (21)

Legend [1] PPH box includes oxytocin, Methergin, misoprostol, different IV cannulas, blood sample bottles, tourniquet, syringes, plaster to fix cannula, catheter size 16 with urobag, infusion set, blood set, sterile gloves, cotton swabs, scissors, fluids (ringers lactate and sodiumchloride), 3-way connectors, oxygen face mask, spculums, sponge holding forceps, condom tamponade and catheter, uterine pack

The participants mentioned that they felt important to the development process. One fifth of the participants (18%, n=37) commented that they would have liked more training opportunities and a better location for the four-day meeting.

VI: Final guideline development and evaluation

The obstetric health care providers had no further comments six weeks after guideline distribution. The final versions of both guidelines were approved by all obstetricians, head midwives and participating stakeholders. The final guidelines were distributed four months after the initiation of the project and further implementation followed in the hospitals. The Ministry of Health technically supported the abovementioned development process and accepted the guidelines as national guidelines. The guidelines were reviewed by health providers two years after initial implementation during a second national conference, and were adapted with new recommendations accordingly.

DISCUSSION

We have presented the participatory approach of the development process of context-tailored national obstetric guidelines on HDP and PPH in Suriname. The process consisted of six steps: (1) determination of how and why women died, (2) interviews and observations of local clincal practice, (3) review of international guidelines, (4) development of a primary set of guidelines, (5) initiation of a national discussion about the guideline content and (6) consensus-based finalization of both guidelines. The most important enabler of succesful guideline development was the bottom-up approach with early involvement of local, intrinsically motivated, health care providers. Important barriers were the inconsistencies between international recommendations, the unavailability of easily adaptable guidelines and the use of several different international guidelines by health care providers which differed among each other.

In the assessment of causes of maternal deaths due to HDP and PPH in Suriname, we found that insufficient quality of care played the most important role. This led to the development of the guidelines. Our approach is aligned with the recommendations from the obstetric transition model, in which evidence-based

guideline implementation is a key intervention to further reduce maternal mortality in countries in the third stage of transition.[26,27] Contrary to the more common maternal health guideline development approach (with a top-down mentality, in which experts distribute knowledge or guidelines without involvement of target users), our guideline development approach demonstrates how to succesfully bridge the gap between evidence-based international recommendations and local realities by involving end users from the earliest phases of guideline development to enhance final guideline use.[3,4,8,27] This is crucial, as merely the existence of (international) guidelines does not guarantee implementation. Our assessment of practice in the hospitals in Suriname showed that guidelines for HDP and PPH were not routinely used and quality of decision-making was based on experience rather than evidence, as often reported from similar settings.[5,7,8,28] Local health professions often considered the international guidelines unfeasible and impractical. Next to this, similar to other studies, we found that well-established international guidelines on HDP and PPH differ significantly in their recommendations and interpretation of underlying evidence that resulted in these recommendations.[29-31] This suggests that a critical evaluation is necessary of how available evidence is used to develop global obstetric guidelines. There were substantial differences in the management of HDP and PPH between hospitals. This is in part a reflection of the various clinical practices that influence care in Suriname with influences from Europe, the United States and the WHO. Yet, even in high-income countries with national guidelines endorsed by professional organizations, inter-hospital differences in management of HDP and PPH are reported.[32,33]

These findings underline the importance of involving also the end users in the guideline development process (i.e. health care providers and stakeholders involved in pregnancy, delivery and postpartum care).

Important barriers of guideline development that need to be elaborated upon is that some recommendations are not immediately accepted. In Suriname, for example, the use of magnesium sulfate for prevention of eclampsia was initially not accepted by all as healthcare workers were not yet familiar with this.

Table 4. 'Key discussion points' during the HDP guideline development process

	Discussion points	Evidence-based consensus
Definition		
1	Can you diagnose severe pre-eclampsia without proteinuria?	Yes, if severe hypertension is accompanied by hematologic, renal, neurological, hepatic or pulmonary complications.
Prevention		
2	Which women should receive aspirin therapy for the prevention of pre-eclampsia?	All women with an obstetric history of pre-eclampsia should be administered 100mg of aspirin during their 16th and 37th week. Women with cardiovascular risk factors may be counselled for its use as well.
Therapy		
3	Which antihypertensive therapy is preffered?	Methyldopa is first choice, followed by hydralazine or labetalol. Nifedipine is first choice postpartum.
4	In severe HDP, what should be given first: antihypertensives or magnesiumsulfate?	Magnesium sulfate (4 gram in 30 minutes, followed by 1 gram per hour) is initiated immediately; hypertensive medication will be added depending on the blood pressures.
5	Can magnesium sulfate be administered by nurses or midwives prior to consultation with a doctor?	In emergency situations nurses or midwives can administer magnesium sulfate before or during consultation with a doctor. It should never be administered over the same tap as oxytocin.
6	Is magnesium sulfate therapy without a loading dose an option when severe pre-eclampsia presents without clinical symptoms?	International evidence and recommendations suggest always using a loading dose, as the maintenance dose does not give the magnesium plasma rise that is necessary to prevent a seizure. When magnesium sulfate is given, it should be given adequately and not stopped during (caesarean) delivery.
7	Should magnesium sulfate therapy be continued in caesarean section with spinal analgesia?	Magnesium sulfate should be continued during the delivery or caesarean section, as the intra partum risk of eclampsia is highest.
8	Can nifedipine and magnesium sulfate therapy be combined?	There is a potential theoretical interaction between the two, leading to hypotension and neuromuscular blockade effects, although this is seldom reported. Regular monitoring is recommended.

Table 4. Continued

	Discussion points	Evidence-based consensus
9	Should a fluid preload be administration before intravenous antihypertensive or magnesium sulfate therapy?	No, because the risk of fluid overload (and subsequent pulmonary oedema) is high in severe pre-eclampsia. Fluid preloading is acceptable in hypovolemia. Early consultation of an anaesthesiologist is advised.
10	Is diazepam of added value to magnesium sulfate in the treatment of eclampsia?	Magnesium sulfate is the drug of choice for treating eclamptic seizures. Diazepam is not advised by international guidelines. During the discussion it was decided upon that diazepam use should be limited to unremitting seizures.
Other		
12	How can we define "stabilization" in eclampsia or severe pre-eclampsia?	The definition of stabilization of pre-eclampsia and eclampsia is: (1) stable blood pressure (RR 130-150 / 70-100); (2) adequate magnesium sulfate (loading dose must be administered); (3) platelets of >80); (4) fluid restriction of <1.5 liters. Stabilization is not time-dependent and can be reached even within an hour if management is adequate.
13	When and how should the pregnancy be terminated in eclampsia or severe pre-eclampsia?	The delivery should not be terminated until the mother is stable (see point 13). The termination of pregnancy is on maternal indication. Vaginal delivery should be strived for whenever feasible without foetal compromise.
13	How often should vital signs be checked and what should be checked?	Every 15 minutes (4 times), every 30 minutes (4 times), every hour (4 times), every two hours (4 times), followed by regular checks in case of normal blood pressures.
14	When is admission to the Intensive Care Unit indicated?	In any case of organ dysfunction, such as pulmonary oedema, neurological complications, HELLP, etc.

Table 5. 'Key discussion points' during the PPH guideline development process

	Discussion points	Consensus
Definition		
1	Should the threshold for PPH be blood loss of 500mL (WHO) or 1000mL (Netherlands)?	Blood loss after vaginal delivery is often underestimated. Therefore, blood loss of 500mL will be considered PPH.
2	How should the blood loss be measured, by a measuring cup, by weight or estimation)	Blood loss needs to be measured by measuring cup or by weight (minus the pad). To be precise, it is advised to exchange the pads just after childbirth to subtract the amniotic fluid loss.
Prevention		
3	Should oxytocin prevention after childbirth always be available and given, including in rural areas?	The cost-efficacy was discussed and health care workers of the interior (n=12) and the different stake holders agreed that oxytocin should be made available in the interior. Misoprostol use in the interior is avoided as much as possible to avoid unsafe abortion.
4	Can the oxytocin-infusion used for uterine stimulation be used as preventive measure for PPH?	A calculation of the blood oxytocin concentration after bolus or infusion revealed that an extra (intravenous or intramuscular) 5-10 units of oxytocin bolus is necessary for adequate prevention op PPH based on international recommendation.
5	Which health care providers should be permitted to perform controlled cord traction?	Midwives should all be competent in performing controlled cord traction. If they do not feel competent to do so, they should be trained by more experienced personnel.
Therapy		
6	Misoprostol is frequently used in PPH in Suriname, what is the additional value on top of adequate oxytocin infusion?	If oxytocin is adequately administered (an extra shot of 5 units plus continuous infusion of 10 units in maximum four hours), misoprostol has no additional value. If oxytocin is not available, or the uterus does not contract sufficiently, misoprostol can be given.
7	What should the oxytocin regimen be in caesarean section?	Oxytocin 5 units slowly intravenously, followed by an infusion (10 units in four hours) is advised in all caesarean sections.

Table 5. Continued

	Discussion points	Consensus
Fluids and blood products		
8	In severe PPH should crystalloids or colloids be used?	International recommendations show no better outcome when using colloids.[d] Colloids are more expensive, adverse effects have been reported and there is no decrease in the risk of respiratory problems due to pulmonary oedema.[e] The preference is to use crystalloids.
9	What is the ideal ratio for the transfusion of packed cells, fresh frozen plasma and platelets?	Ratio 1 : 1 : 0. For every packed cell also fresh frozen plasma. In acute severe blood loss it is advised to initiate the fresh frozen plasma transfusion, as it is generally available more rapidly than packed cells. Platelet transfusion is given for specific indications (coagulopathy).
Other		
10	Should a parthograph always be used?	The partograph is an important tool to assess the progress of labour. Induction or slow progress of labour and oxytocin-stimulation are merely a few examples of PPH risk factors.
11	When is tranexamic acid recommended and what is the risk for a subsequent thrombo-embolism?	Tranexamic acid (1 gram in 10 minutes) is recommended in cases of 1000 mL blood loss or more. In ongoing blood loss, it is advised to repeat this after 30 minutes. It should not be administered to women with a contra-indication for antifibrinolytic therapy (e.g. thrombosis in pregnancy). The results of the WOMAN trial are to be published.
12	What are more affordable options for an intra-uterine tamponade balloon such as the Rush or Bakri?	Intra-uterine balloon can be made with condoms and a urinary catheter. Recommendations were to insert a large vaginal tampon after the balloon insertion to prevent displacement.
13	How often should vital signs be monitored after severe PPH?	Every 5 to 10 minutes during blood loss. After PPH vitals should be recorded after 30 minutes, one hour, 2 hours, 4 hours and 8 hours.

Another barrier for Suriname is the fact that there is currently no regulatory framework for health professionals. We believe such framework would be relevant to reduce maternal deaths, especially by helping health care workers to monitor their delivered quality of care. A general barrier for the development of context-tailored obstetric guidelines is the fact that it is time consuming and resource demanding. We noticed that early involvement of end users, understanding their barriers and engaging all health care professionals are essential to ensure a fast guideline development process. If more global consensus on the most important obstetric complications would be attained, with recommendations tailored at region or health care system resources and include easily-adaptable flowcharts or checklists, the local guideline development would be much more feasible. The WHO Handbook for Guideline Development is an example of a comprehensive tool for evidence-based guideline development, but also a very large document and it uses a time-consuming process that seems not readily achievable for most LMIC.[34] The recently published PartoMa study from a low-resource referral hospital in Zanzibar, Tanzania, is one of the few examples of a systematic approach to evidence-based international recommendations adaptation to local reality and evaluation of it's impact on health outcomes. Their 'bottom up' approach was similar to ours and appeared to be associated with significant reductions in stillbirths and improvement of treatment of hypertensive disorders of pregnancy.[6,7,35] The PartoMa Guideline Development in Zanzibar and our strategy in Suriname were both achievable due to the smaller size of the island or country.[6,7,35]

However, when healthcare workers are fully engaged in the quality cycle of plan-do-check-act, nationwide improvement can also be made in larger countries.[36]

Strengths and limitations

This is the first evaluation of the development of national obstetric guidelines in a middle income country, and can serve as an example for low and middle income countries in the process of developing contextually-tailored guidelines. There was a high rate of agreement and the guideline development process was completed

very steadily, in only four months. A limitation to consider is that our guideline development process was conducted in a small country and thus, for larger countries this might not be applicable directly. Another limitation is that qualitative data on maternal mortality most likely did not reflect 'standard' management of HDP and PPH before the guideline development proces.

We therefore recommend others to perform a study before guideline development to better assess the current situation and be able to do a before-after analysis. We also acknowledge that the evaluation surveys were not conducted by an independent party and may not have captured all the dimensions of the development process. Nevertheless, if the incidence of maternal mortality and severe morbidity declines, the awareness created among healthcare providers by recent publications on local maternal mortality in Suriname together with the development of the guidelines will likely have contibuted, especially as no other major interventions related to HDP and PPH have taken place the past decade.[11,13]

In the context of research, we are evaluating implementation of the guidelines by criteria-based audits embedded in a prospective cohort study on severe maternal morbidity and mortality due to HDP and PPH, currently ongoing in Suriname. Yet, it remains a recommendation to independently evaluate the impact on core outcomes in order to evaluate actual quality improvement.

CONCLUSION

Bottom-up development of context-tailored guidelines are achievable within a reasonably short timeframe. Important barriers for the guideline development process are the discrepancies between international recommendations, which require local consensus to be reached on key issues, and the unavailability of easily adaptable guidelines. The main enabler for both development and implementation is the involvement of local birth attendants from the early phases onwards to ensure use in local reality, drive change and create sustainable adherence. We recommend bottom-up context-tailored guideline development with early involvement of the end users.

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Supplementary file 1. Comparison of HDP practice in Suriname

Hypertensive disorders in pregnancy – The variation in practice between the four hospitals in Paramaribo - Suriname

		Hospital A (2016)	Hospital B (2016)	Hospital C (2016)	Hospital D (2016)	The final national guideline
Definitions	Pre-eclampsia	*BPs ≥ 140 mm Hg* **AND/OR** *BPd ≥ 90 mm Hg (measured twice at least 4 hours apart)* **OR** *BPd≥ 110 mm Hg; all after GA 20 weeks;* **with** *proteinuria*	BPd ≥ 90 (measured twice at least 4 hours apart) **OR** BPd≥ 110 **OR** increase of BP 15-20 compared to pre-pregnancy BP; all after GA 20 weeks; **with** proteinuria **OR** clinical symptoms	*BPs ≥ 140* **AND/OR** *BPd ≥ 90 (twice; interval 4h)* **OR** *BPs≥ 110; all after GA 20 weeks;* **with** *proteinuria*	BPs ≥ 140 **AND/OR** BPd ≥ 90 mm Hg (twice; interval 4h) **OR** BPd ≥ 110 mm Hg; all after GA 20 weeks; **with** proteinuria	BPs ≥ 140 mm Hg **AND/OR** BPd ≥ 90 (2x, interval 4 -6h) OR increase BPs >30 **OR** BPd >15 mmHg **with** proteinuria OR clinical symptoms
	Severe pre-eclampsia	*Pre-eclampsia with BP diastolic ≥ 110 mm Hg with clinical symptoms*	Not specified	*Pre-eclampsia with BP diastolic ≥ 110 mm Hg* **OR** *clinical symptoms*	Not specified	BPd ≥ 110 mmHg (once) **with** proteinuria **OR** organ dysfunction (renal, liver, hematological, neurological, pulmonal)
	Eclampsia	*Generalized tonic-clonic seizures, with no other cause than pre-existent pre-eclampsia*	Convulsion in a pre-eclamptic patient with no other cause	Convulsion in a pre-eclamptic patient with no other cause	Convulsion in a pre-eclamptic patient with no other cause	Tonic-clonic seizures with no other attributable cause than pre-eclampsia
Hypertensive	Calcium	*No*	History of IUGR or pre-eclampsia	No	No	Low intake → 2 grams in 2-3 trimester
	Aspirine	*Chronic hypertension or medical history of IUFD or IUGR due to pre-eclampsia*	History of IUGR or pre-eclampsia	No	No	High risk → 100mg in GA 16-37
	Admission criteria	BPs ≥ 160 **AND/OR** BPd ≥ 110 **AND/OR** clinical symptoms	Not specified	Not specified	Not specified	Severe PIH (persistent BPs ≥ 150/100), pre-eclampsia / HELLP / eclampsia, foetal indication
	Oral initiation	*BPd ≥ 100*	Not specified	BPd ≥ 100 mm Hg (twice)	BPd ≥ 100 **OR** BP increase >30	BPs ≥ 150 **OR** BPd ≥ 100
	Parenteral initiation	*BPd ≥ 110*	Not specified	BPd ≥ 110 mm Hg	BP diastolic ≥ 110 mmHg > once	BPd ≥ 110
	Oral drug choice	*1. methyldopa 250-750mg 2-3* *2. hydralazine 25-50 2-3dd*	1. methyldopa 250-500mg 2-3 2. hydralazine 25-50 2-3dd	1. methyldopa 250-500mg 2-3 2. hydralazine 25-50 2-3dd 3. labetalol 100-200mg 2dd	1. methyldopa 250-500mg 2-3 2. hydralazine 25-50 2-3dd	1. methyldopa 250-1000mg 3-4dd 2. hydralazine 25-75mg 3dd 3. labetalol 50-200mg 3dd
	Antepartum					
	Postpartum	*nifedipine 20mg 2dd*	nifedipine 20mg 2dd	nifedipine 20mg 2dd	nifedipine 20mg 2dd	nifedipine 5-40mg 3dd
	Parenteral drug choice	*1. hydralazine via perfusor* *2. hydralazine 5mg i.v.* *3. ketanserine or labetalol* *Perfusor available*	1. hydralazine via perfusor 2. hydralazine 5mg i.v. 3. labetalol Perfusor available only in ICU	1. hydralazine via perfusor 2. hydralazine 5mg i.v. Perfusor available	hydralazine 5mg i.v. Perfusor not available	1. hydralazine 5-10mg à 20-40 min. **OR** by infusion system 2. labetalol 1-2 mg/kg in 20 min. Continue 20-70mg/hr.
$MgSO_4$	Indication	*Eclampsia; severe pre-eclampsia; neuroprotection*	Eclampsia; pre-eclampsia	Eclampsia; severe pre-eclampsia	Eclampsia; severe pre-eclampsia; pre-eclampsia with symptoms	Eclampsia; severe pre-eclampsia (BPd ≥ 110 OR clinical symptoms); neuroprotection
	Loading dose	*4 grams / 30 minutes*	2 grams / 30 minutes	4-6 grams / 30 minutes	1 gram / 30 minutes	4-6 grams / 30 minutes
	Maintenance dose	*1 gram / hour*	1 gram / hour	1 gram / hour	1 gram / hour	1 gram / hour
	Dose repeated seizure	*2 grams / 5 minutes*	None (diazepam)	None (diazepam)	None (diazepam)	2 grams / 5 minutes
	Stop treatment	After 48 hours	After 24 hours and stable	After 48 hours	After 48 hours and stable	24 – 48 hours (max 7 days; measure plasma $MgSO_4$)
	Diazepam indication	If no iv-access	If no iv-access or in repeated seizure	If no iv-access or in repeated seizure	In seizures (whether or not on $MgSO_4$)	If no iv-access; when $MgSO_4$ shot given twice
	Oxygen	*Eclampsia: 10 L NRM*	No	Eclampsia: 5-10 L NRM	No	Eclampsia: 15 L NRM
	Intravenous access	*1 in pre-eclampsia; 2 in eclampsia*	1 in pre-eclampsia and eclampsia	1 in pre-eclampsia; 2 in eclampsia	1 in pre-eclampsia and eclampsia	2
Fluids	Before i.v. drugs	500mL NaCl 0.9% quick	1000mL gelofusine quick	500mL Ringers **OR** gelofusine	No fluids	No fluids
	Maintenance	500mL Ringers à 8 hours (no gelofusine, glucose/NaCl 0.9%, glucose 5%)	500mL glucose/NaCl 0.9% à 6 hours	First 1000mL Ringers in 6 hours, then 500mL glu/NaCl 0.9% à 8 hours	500mL Ringers **OR** NaCl 0.9% à 8 hours	Max. 1500mL in 24 hours. Preference for Ringer's Lactate or NaCl 0.9%
Monitoring	Vital signs RR <12 RR ≥ 22 OR $MgSO_4$	Every 6 hours 4x once per hour, then every 4 hours	Every 4 hours Every 2-3 hours	Every 2-3 hours 4x every ½ hour, 4x every hour	Every 6 hours Every 4 hours	Every 4 hours (intrapartum every ½ hour) Every ½ hr (4x), 1hr (4x), 2 hrs (4x), 4 hrs (4x)
	Fluid balance	*Pre-eclampsia*	Pre-eclampsia / HELLP	Severe pre-eclampsia	Pre-eclampsia	Every admission of hypertensive disorders
	Blood tap	*2x per week*	2x per week	2x per week	3-4x per week	2x per week
	Doppler	GA <27	GA <34	GA <30	GA <20	GA <27
	CTG	GA ≥27	GA ≥34	GA ≥30	GA ≥20	GA ≥27
Delivery	Corticosteroids	GA 26 – 34 *Dexamethasone 12mg 2dd IV; 12hrs*	Severe pre-eclampsia and GA 28-34 Dexamethasone 12mg twice; 12hrs	Delivery expected in GA 27-34 Dexamethasone 12mg twice; 12hrs	Severe pre-eclampsia and GA 28-34 Dexamethasone 12mg twice; 12hrs	GA 26 – 34 Dexamethasone 4 x 6mg; 12 hours apart total 48 hours]
	Eclampsia late	*In case of heavy illness*	Not present	In case delivery room	Not present	In case delivery room
	Timing mild PE	GA 37 Induction (balloon, misoprostol)	Dependent on gynaecologist Induction (misoprostol) or C-section	GA 37, induction Induction (balloon, misoprostol)	GA 37 Induction (misoprostol) or C-section	GA 37; preference for vaginal birth, with induction (depending on BISHOP → balloon/misoprostol/oxytocine)
	Timing severe PE	GA ≥27 *C-section advised 48 hours of stabilization*	GA ≥34 C-section after stabilization	GA ≥30 C-section / induction after stabilization	GA ≥22 C-section after stabilization	GA <27 induction, GA ≥ 27; preference for induction. Caesarean in case of failed induction or fetal indication
Postpartum	Duration of admission	At least 24 hours post partum	At least 24 hours post partum	At least 24 hours post partum	At least 24 hours post partum	At least 24 hours post partum and stable (BP normalized, urine output normal, lab results improved)
	Antihypertensives	No target BP; switch to nifedipine	No target BP; switch to nifedipine	No target BP; switch to nifedipine	No target BP; switch to nifedipine	BPs 130-150 and BPd 80-110; switch to nifedipine
	Blood tap	If necessary	One day post partum	If necessary	Two days post partum	One day post partum
	Perinatal dilatation	7 days	7-10 days	7 days	7 days	7-10 days; one week

Supplementary file 2. Comparison of PPH practice in Suriname

Postpartum hemorrhage – The variation in practice between the four hospitals in Paramaribo - Suriname

		Hospital A (2016)	Hospital B (2016)	Hospital C (2016)	Hospital D (2016)	The final national guideline
	Definition PPH	500mL blood loss or more after vaginal delivery	500mL blood loss or more after vaginal delivery	500mL blood loss or more after vaginal delivery	500mL blood loss or more after vaginal delivery	500mL blood loss or more during and after childbirth
	Definition severe PPH	1000mL blood loss or more	Not specified	Not specified	Not specified	1000mL blood loss or more or blood loss with clinical hypovolemia during and after child birth
	Call for help (supervisor)	500mL blood loss or more (general doctor) 1000mL blood loss or more (gynaecologist)	Not specified	500mL blood loss or more	500mL blood loss or more	500mL blood loss or more (call general doctor) 1000mL blood loss or more (call gynaecologist)
	Risk factors	Not specified	Prolonged labor, twin pregnancy, macrosomia, high parity, uterus myomatosis	Not specified	Not specified	Risk factors grouped (see guideline for elaboration): - General (e.g. age >40, BMI >35, uterus myomatosis) - Obstetric history (e.g. grande mult, caesarean, etc) - Current pregnancy (macrosomia, pre-eclampsia, etc) - During delivery (prolonged labor, etc) - Post partum (full bladder, retained placenta, etc).
Prevention	**Partograph**	On indication (prolonged labor, caesarean in history, on request of physician)	Sometimes	Never	Never	Always recommended
Prevention	**Oxytocin in the 3rd stage of labor**	Caesarean – always Vaginal birth – always (before delivery of placenta) 5-10 IU i.m. or slowly i.v. (2 minutes)	Caesarean – always Vaginal birth – in patients with high-risk for PPH (done after delivery of placenta) 5-10 IU i.m. or slowly i.v. (2 minutes)	Caesarean – always Vaginal birth – in patients with high-risk for PPH (done after delivery of placenta) 5-10 IU i.m. or slowly i.v. (2 minutes)	Caesarean – always Vaginal birth – in patients with high-risk for PPH (done after delivery of placenta) 5-10 IU i.m. or slowly i.v. (2 minutes)	Caesarean – always Vaginal birth – always (before delivery of placenta) 5-10 IU i.m. or slowly i.v. (2 minutes)
Prevention	**Measurement of blood**	- Measurement cup (mL) - Liquid (blood) removed from blood clots with a swe. Measurement done of only the blood clots.	- Measurement cup (mL) - Liquid (blood) removed from blood clots with a sieve. Measurement done of only the blood clots.	- Measurement cup (mL) and / or scale (kg) - Liquid (blood) and blood clots measured	- Measurement cup (mL) - Liquid (blood) removed from blood clots with a sieve. Measurement done of only the blood clots.	- Measurement cup (mL) and / ore scale (kg) - Measure liquid (blood) and bloodclots all together. Subtract the estimated amniotic fluid.
Management	**Oxytocin i.m. / i.v.**	Repeat 5-10 IU shot i.m. or i.v.	5 IU shot i.m. or i.v.	5 IU shot i.m. or i.v.	10 IU shot i.m. or 5 IU shot i.v.	10 IU shot i.m. or i.v.
Management	**Oxytocin infusion**	10 IU in 500mL / 4-6 hours During at least 24 hours	5 IU in 500mL / 6 hours Until bleeding stops	10-20 IU in 500mL / 4 hours During at least 4 hours	10 IU in 500mL / 4-6 hours Until bleeding stops	10 IU in 500mL / 4 hours
Management	**Misoprostol**	400 – 800 micrograms rectal	400 – 800 micrograms rectal	400 micrograms rectal	400 – 800 micrograms rectal	Not first choice, as misoprostol is not beneficiary when adequate oxycotin dosis is given.
Management	**Methergin**	Not prescribed	0.2 mg i.m. if bleeding persists	Not prescribed	Not prescribed	0.2 mg i.m.
Management	**Tranexamic acid (Cyclokapron)**	1 gr i.v. slowely in persistent bleeding	2 gr i.v. slowely in severe and persistent bleeding	2 gr i.v. slowely in severe and persistent bleeding	Not prescribed	1 gram i.v. slowely when 1000mL blood loss or more
Management	**Calcium gluconate**	1 gram i.v. After transfusion of 4 blood products	1 gram i.v. After transfusion of 6 blood products	1 gram i.v. After transfusion of 4 blood products	Not prescribed	1 gram i.v. After transfusion of 4 blood products
Management	**I.V. access**	2 i.v. access lines (> 1000 mL blood loss)	Not specified	Not specified	Not specified	2 x intravenous access (preferably green or grey)
Management	**Infusion**	Ringer's Lactate or Sodium Cloride 0.9%	Ringer's Lactate or Glucose 5%	Sodium Cloride 0.9%, Glucose 5% or Gelofusine	Ringer's Lactate or Sodium Cloride 0.9%	Ringer's Lactate or Sodium Cloride 0.9% Infuse 1 : 1 (blood loss : infusion), max 3 liters
Resuscitation	**Oxygen**	10 L / min in 1000 mL blood loss or more	Sometimes in severe blood loss	10 L / min in 2000 mL blood loss or more	Sometimes in severe blood loss	10 – 15 L / min in 1000 mL blood loss or more
Resuscitation	**Transfusion indication**	Hb < 4 mmol/L	Hb < 5 mmol/L	Hb < 3.5 mmol/L or Ht < 0.20	Hb < 4.5 mmol/L and complaints	Hb < 4.0 mmol/L or Ht < 0.20, 1000 mL blood loss or more and persistent or with symptoms of hypovolemic shock
Resuscitation	**Blood products ratio**	2 PC : 1 FF	2 PC : 1 FFP	1 PC : 2 FFP	2 PC : 1 FFP	1 PC : 2 FFP (in massa transfusion 4 PC : 4 FFP : 1 TC)
Resuscitation	**Surgical and other**	Vaginal tampon; Hysterectomy	Vaginal tampon; Hysterectomy	Vaginal tampon; Hysterectomy	Vaginal tampon; Hysterectomy	Vaginal and uterine packing (gauzes); balloon tamponade (Bakri, Foley, condom); B-lynch; bilateral ligation of uterine (or internal iliac) arteries; hysterectomy (rather sooner than later)
Vital signs	**Measurements of**	Blood pressure, pulse, temperature , blood loss, tone of uterus	Blood pressure, pulse, temperature, blood loss, tone of uterus	Blood pressure, pulse, temperature, blood loss, tone of uterus	Blood pressure, pulse, temperature, blood loss, tone of uterus	Blood pressure, pulse, **respiratory rate, saturation,** temperature, blood loss, tone of uterus, **urinary output**
Vital signs	**Timing of monitoring** - after a normal delivery - during hemorrhage - after hemorrhage	Directly; after 1 hour; after 8 hours Not specified Directly; after 1 hour; after 4 hours	Directly; after 1 hour; after 8 hours Not specified Directly; after 1 hour; after 8 hours	Directly; after 1 hour; after 8 hours Not specified Directly; after 1 hour; after 2 hours	Directly; after 1 hour; after 8 hours Not specified Directly; after 1 hour; after 8 hours	Directly; after 1 hour; after 8 hours Every 10 minutes Directly; after 30 minutes; 1 hour; 2 hours; 8 hours
Vital signs	**MEOWS score performed**	Yes	No	No	No	Not specified
	Follow up in severe PPH	- Blood exam (Hb, Ht, Tr, INR, fibrinogen) - Performed a day later - Discharge not specified	- Blood exam (not specified) - Performed same day - Discharge not specified	- Blood exam (not specified) - Performed a day later - Discharge not specified	- Blood exam (not specified) - Performed same day - Discharge not specified	- Blood exam (Hb, Ht, Tr, INR, APTT, PT fibrinogen, electrolytes, creatinine and liver enzymes) - Performed 4 hours later and 24 hours later - Discharge (by doctor) after at least 24 hours
	PPH-box in delivery room	Yes	No	Yes	No	Yes, should always be
	PPH-checklists or flow charts in delivery rooms	Yes	No	Yes	No	Yes, should always be

Supplementary file 3. Comparison of international HDP guidelines

	WHO (2011)	ACOG (2013)	Queensland Brisbane (2016)	NVOG (2011)
Definition				
Pre-eclampsia	Onset of new episode of hypertension during pregnancy (persistent diastolic BP ≥ 90 mm Hg) with substandial proteinuria (>0.3 g/day)	BP systolic ≥ 140 and/or diastolic ≥ 90 mm Hg (measured twice at least 4 hours apart) after GA20 OR BP systolic ≥ 160 and/or diastolic ≥ 110 mm with either proteinuria OR with severity symptoms	Hypertension (BPs≥ 140 OR BPd ≥ 90) after 20 weeks of gestation on 2 or more occassions accompanied by one of the following: proteinuria (>30mg/mmol), creat >90, oliguria, thrombopenia (<100), hemolysis, raised transaminases, DIC, neurological symptoms, pulmonary oedema or foetal growth restriction.	Pregnancy induced hypertension (BP systolic ≥ 140 and/or diastolic ≥ 90 mm Hg after GA 20, meassured twice in women with normal previous BP. BP should be normal within 3 months post partum) with proteïnuria (>0.3g/day)
Severe PE	Severe hypertension (not defined), heavy proteinuria or substantial maternal organ dysfunction. Early onset (before 32-34 weeks) and foetal morbidity are used as independent severity criteria in some countries	Systolic ≥ 160 or diastolic ≥ 110 mm Hg (measured twice at least 4 hours apart while patient is on bed) AND thrombopenia <100 OR impaired liverfunction or epigastric pain OR impaired renal function (creatinine 2x normal) OR pulmonary oedema OR cerebral/ visual disturbances.	[Magpie Trial] BPs ≥ 170 or BPd≥ 110 mm Hg AND 3+ proteinuria OR BPs ≥ 150 or BPd≥ 100 mm Hg AND 2+ proteinuria AND 2 severity symptoms OR pre-eclampsia with at least one sign of central nervous system irritability	Systolic ≥ 160 or diastolic ≥ 110 mm Hg OR clinical symptoms of pre-eclampsia (headache, upper-abdominal pain, nausea) OR proteïnuria >5 g / 24 hours. [Proteinuria can remain absent]
Eclampsia	Generalised seizures in addition to pre-eclampsia criteria	New-onset grand mal seizures in a woman with pre-eclampia	One or more seizures superimposed on PE (HT/proteinuria may be absent)	Not specified
Prevention				
Calcium	When low calcium intake (<900mg/ day)	In populations with low calcium intake	In high risk women with low calcium intake	Not specified
Aspirin	75mg/ day in high risk women, initiate GA<20 weeks	In high risk women, start 60-80 mg daily in late first trimester	Moderate to high risk of PE; 100mg/day , initiate <16 weeks. Until 37 weeks or birth of baby (NNT 42)	Not specified
Antihypertensive				
Initiation	Not specified	Persistent BP systolic ≥ 160 mm Hg OR diastolic ≥ 110 mm Hg	BP systolic ≥ 160 OR diastolic ≥ 100 mm Hg	Systolic ≥ 160 OR diastolic ≥ 110 mm
Drug choice	Hydralazine, methyldopa, labetalol, nifedipine, ketanserin, and others are compared.	Labetalol, nifedipine, methyldopa	Oral: methyldopa, labetalol, oxyprenolol, hydralazine, nifedipine, prazosin, clonidine. I.V. nifedipine, hydralazine, labetalol	Methyldopa, labetalol, nifedipine

Supplementary file 3. Continued

	WHO (2011)	ACOG (2013)	Queensland Brisbane (2016)	NVOG (2011)
Magnesium sulfate				
Indication	Eclampsia; severe PE	Eclampsia; severe PE	Eclampsia; HELLP; severe PE; neuroprotection	Eclampsia; severe PE, consider in mild pre-eclampsia
Loading dose	Not specified	4-6 (time ?)	4 g IV in 20 min	4-6 g in 10-30 min
Maintanance	Not specified	1-2 g per hour	1 g per hour	1 g in 60 min
2nd seizure	Not specified	No specific recommendations	2 g in 5 min (may repeat after 2 min) Other possibilities: diazepam 5-10mg IV (2-5mg/min), midazolam 5-10 mg IV in 2-5min	2 g in 5 min (max. twice) Other possibilities: lorazepam 4mg i.v. slowly, sedate and intubate
Stop treatment	Not specified	At least 24 hours after last convulsion	At least 24 hours after birth or last seizure	At least 24 hours after initiation
Other				
Corticosteroids	Not specified	GA <34 weeks	GA <34 weeks	GA <34, birth expected in 2-10 days; Betamethason 12mg i.m. 2x (24hr apart)
Vital signs	Not specified	Every 8 hours	At least every 4 hours	Not specified
Fluids	Not specified	Not specified	No large volumes of fluids. Restrict to 1.5L/24 hrs after birth. Strict fluid balance	Not specified
Delivery timing in severe PE	Unviable: induction. Term: delivery asap Before term: expectant unless uncontrolled hypertension or foetal distress	Depends on severity; GA and NICU-facility. Deliver shoud be shortly after stabilisation.	Stabilise (control hypertension, correct coagulopathy, initiate $MgSO_4$, control fluids) and deliver	Not specified
Post partum medication	Not specified. Severe post partum hypertension; in all women treated antenatally	Not specified. Initiate when BP systolic ≥ 150 OR diastolic ≥ 100 mm Hg.	Avoid abrupt withdrawal of antihypertensives. Cease methyldopa (depression). Consider nifedipine.	Not specified
Other recommendations	Not specified	No NSAIDS, promote breastfeeding. Consider postnatal counseling.	Consider VTE profylaxis (during admission); postnatal counseling. Follow-up 6 weeks	Not specified

Legend: BP = blood pressure, GA = gestational age, HT = hypertension, IV = intravenous, $MgSO_4$ = magnesium sulfate, NNT = number needed to treat, VTE = venous thrombo-embolism, NSAID = non-steroidal anti-inflammatory drugs.

Supplementary file 4. Comparison of international PPH guidelines

	WHO (2011)	ACOG (2013)	RCOG (2014)	NVOG (2011)
Definition	PPH: >500mL Severe PPH >1 L	Vaginal > 500mL Caesarean >1 L	Minor: >500mL Moderate: 1-2 L Major: >2 L	Vaginal > 500mL Caesarean >1 L
Incidence	2%	4-6%	3.7/1000 (> 5 PC)	3.8% (2003) 6.2% (2009)
Risk factors	Minimally described	Elaborately described	Elaborately described with odds ratio	Elaborately described
Prevention	AMTSL (CCT after 30 min)	Not discussed	AMTSL Placenta location	AMTSL
Oxytocin	10 IU i.m. / i.v. in all births	Not specified	Oxytocin 5 or 10 IU i.m. / 5 IE i.v. (CS) Ergometrin 0.5 mg i.m. Combined if Hb low	Oxytocin 5 or 10 IU i.m. / 5 IE i.v. (CS) followed by 10 IU i.v. in 4 hours
Resuscitation				
Access	Not specified	Ample intravenous access	Intravenous access 2x	Intravenous access 2x
Fluids	Crystalloids	Crystalloids	Crystalloids, warm/ rapid Max. 2 L (+ 1.5L colloids)	Crystalloids, warm/ rapid (1 : 1 blood loss)
Oxygen	Not specified	10-15 L per minute	10-15 L / min over NRM	Not specified
Blood products	Not specified	Blood as needed and blood bank notification	As soon as possible 6 PC : 4 FFP	4 PC : 4 FFP
Uterine massage	Recommended, contin-uously. Bimanual, aorta compression advised	Not specified	Not specified	Recommended, continuously
Coagulation screening	Blood loss up to 1500mL or >2 uterotonics	Not specified	>1L blood loss	>1L blood loss or >2L cristalloids
Medical treatment				
Oxytocin infusion	Recommended	10-40 IU i.v. or 10 IU i.m.	5 IU i.v. may repeat or 40 IU in 500mL à 4 hrs	10 IU i.v. followed by 10 IU i.v. à 4 hrs
Misoprostol	If oxytocin not available: 600ug oral or 800ug sublingual	800-1000ug rectal	1000 ug rectal	Not recommended
Ergots	If oxytocin not available Not in retained placenta	Methyl-ergonovine 0.2 mg i.m. every 2-4 hr	Ergometrine 0.5mg i.m. or i.v.	Metergin 0.2mg i.m or i.v.
Others	Not specified	Carboprost 0.25mg i.m. Dinoprostone 20mg PV. Factor VIIa 50-100ug/kg every 2 hours	Carboprost 0.25mg i.m. (max 8 doses)	Sulproston 500 ug / 30 mins (followd by 60-120 ug per hour). Fibrinogen 2g (in >2L blood loss)

Supplementary file 4. Continued

	WHO (2011)	ACOG (2013)	RCOG (2014)	NVOG (2011)
Tranexamic Acid	Recommended in case of persistent bleeding	Not specified	Not recommended	Recommended, 1-2 g
Antibiotic profylaxis in MPR	Ampicillin or cefazolin	Not specified	Not specified	Cefazolin/metronidazol or amoxicillin/clav. acid
Surgical treatment				
Uterine packing	Not recommended	4-inch gauze 5000U thrombin in 5mL saline	Not recommended	Not recommended
Balloon tamponade	Refractory bleeding/ Uterotonics unavailable	Foley (60-80mL) Bakri (300-500mL)	Leave for 4-6 hrs	In refractory bleeding Bakri (300-500mL)
Brace suture	Not specified	B-Lynch, square	B-Lynch, square	B-Lynch, square
Vessel ligation	Uterine and iliac artery	Uterine and iliac artery	Uterine and iliac artery	Not specified
Embolization	If bleeding stable	Not specified	Yes, consider	Yes, consider
Hysterectomy	In refractory bleeding despite vessel ligation	Not specified	Rather sooner than later	In case of placenta accreta, uterine rupture or Jehova's witnesses

Legend: AMTSL = active management of the third stage of labour. CCT = controlled cord traction. FFP = fresh frozen plasma. Hb = hemoglobin. MPR = manual placenta removal. NRM = non-rebreathing mask. PC = packed cells.

Postpartum haemorrhage in Suriname: magnitude, risk factor analysis: an audit of case management

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ABSTRACT

Background: Postpartum haemorrhage (PPH) is the leading cause of direct maternal mortality globally and in Suriname. We aimed to study the prevalence, risk indicators, causes, and management of PPH to identify opportunities for PPH reduction.

Methods: A nationwide retrospective descriptive study of all hospital deliveries in Suriname in 2017 was performed. Logistic regression analysis was applied to identify risk indicators for PPH (≥ 500ml blood loss). Management of severe PPH (blood loss ≥1,000ml or ≥500ml with hypotension or at least three transfusions) was evaluated via a criteria-based audit using the national guideline.

Results: In 2017, the prevalence of PPH and severe PPH in Suriname was 9.2% (n=808/8,747) and 2.5% (n=220/8,747), respectively. PPH varied from 5.8% to 15.8% across the hospitals. Risk indicators associated with severe PPH included being of African descent (Maroon aOR 2.1, 95% CI 1.3-3.3, Creole aOR 1.8, 95%CI 1.1-3.0), multiple pregnancy (aOR 3.4, 95% CI 1.7-7.1), delivery in Hospital D (aOR 2.4, 95% CI 1.7-3.4), caesarean section (aOR 3.9, 95% CI 2.9-5.3), stillbirth (aOR 6.4, 95% CI 3.4-12.2), preterm birth (aOR 2.1, 95% CI 1.3-3.2), and macrosomia (aOR 2.8, 95% CI 1.5-5.0). Uterine atony (56.7%, n=102/180, missing 40) and retained placenta (19.4%, n=35/180, missing 40), were the main causes of severe PPH. A criteria-based audit revealed that women with severe PPH received prophylactic oxytocin in 61.3% (n=95/155, missing 65), oxytocin treatment in 68.8% (n=106/154, missing 66), and tranexamic acid in 4.9% (n=5/103, missing 117).

Conclusions: PPH prevalence and risk indicators in Suriname were similar to international and regional reports. Inconsistent blood loss measurement varied maternal and perinatal characteristics, and variable guideline adherence contributed to inter-hospital prevalence variation. PPH reduction in Suriname can be achieved through prevention by practicing active management of the third stage of labour in every birth and considering risk factors, early recognition by objective

and consistent blood loss measurement, and prompt treatment by adequate administration of oxytocin and tranexamic acid according to national guidelines.

BACKGROUND

Postpartum haemorrhage (PPH) remains the most frequent cause of maternal mortality, accounting for 27% of maternal deaths worldwide.[1] Most of these deaths occur in low- and middle income countries (LMIC) and are associated with limited access to timely and quality care and inadequate availability of resources such as blood products.[2,3] PPH has become more prevalent due to increasing rates of advanced maternal age, obesity, preeclampsia, prolonged labour, caesarean delivery, and multiple pregnancies.[4-7] Besides, PPH contributes to severe maternal morbidity and permanent disability worldwide.[8] Global PPH prevalence ranges from 6 to 10% but varies widely between and within countries.[9-11] In Latin America and the Caribbean (LAC), the estimated prevalence of PPH is between 8.2% and 8.9%, and severe PPH (defined as blood loss ≥ 1,000 ml) occurred between 3.3% and 5.3% of births.[10,11]

The main causes of PPH are the "4 T's": uterine atony (tone, 80%), genital tract laceration (trauma, 13%), retained placenta or placental tissue (tissue, 5%), and coagulopathy (thrombin, 2%).[8,12,13] While risk indicators are associated with various socio-demographics, pregnancy complications, and delivery characteristics, many women experience PPH without exhibiting any specific risk indicator.[12,14,15] Therefore, prevention, early recognition, and prompt PPH treatment for each woman remain the cornerstone to avoid maternal morbidity and mortality.[13,17,18]

In Suriname, PPH was the leading direct cause of maternal mortality responsible for 20% (n = 13/65) of deaths from 2010 to 2014. Delays in diagnosis, monitoring, and treatment were critical factors contributing to these deaths.[18] However, no detailed information on PPH prevalence, causes, and risk indicators were available for Suriname. Therefore, this study aimed to (1) assess the prevalence of PPH, (2) identify risk indicators and underlying causes of PPH, and (3) evaluate the management of severe PPH by performing a criteria-based audit. Specific identified

gaps provide evidence to guide further efforts to reduce PPH-related maternal mortality and morbidity.

METHODS

Study design and setting: A nationwide retrospective descriptive study of all hospital deliveries was conducted in Suriname between January 1st and December 31st, 2017. In addition, a criteria-based audit was performed to analyse case management of severe PPH.

Suriname is a middle income country on the northern coast of South America with the lowest population density on the continent. More than 80% of the estimated population of 583,200 lives in the urban and rural coastal lowlands.[19] The ethnic distribution includes Hindustani (27%), Maroon (22%), Creole (16%), Javanese (14%), mixed (combination of ethnicities – 13%), Indigenous (4%), and others (Chinese, Brazilian, Caucasian, and unknown – 4%).[20] Maroons and Creoles are of African ancestry, while Hindustani and Javanese are of Asian descent. Of the approximately 10,000 deliveries per year, 92% are institutional (86% hospital, 6% primary care).[20,21] Four out of five major hospitals are in the capital Paramaribo; one is located at the western border of Suriname (Nickerie). All complicated pregnancies and births in primary care, including women with ongoing or severe PPH, are transferred to the nearest hospital. Every hospital has an intensive care unit (ICU). A national PPH guideline developed in 2016 incorporates international recommendations for prevention (screening for and treating anaemia and active management of the third stage of labour (AMTSL)), early recognition (measurement or visual estimation of the amount of blood loss and clinical signs), and management (oxytocin prevention and therapy and tranexamic acid use).[21]

Data collection and variables: Birth attendants documented each birth with a gestational age ≥ 22 weeks and a birth weight of ≥ 500 grams in a parturition book. The blood loss amount was usually visually estimated. In case of estimated high blood loss, the measurement was taken using a measuring jug. However, in two hospitals, only blood clots were measured.[21] Hospital administrative personnel

anonymously entered data from the paper parturition books into a password-secured digital database on a daily basis. The datasets from the five hospitals were merged, yielding one national delivery database for 2017. Missing and incorrect data were crosschecked with the original parturition books and medical files. The Surinamese Obstetric Surveillance System (SurOSS) identified all women with potentially life-threatening disorders in pregnancy between March 2017 and February 2018.[22] Study data for the criteria-based audit were derived from this database. The primary outcome variable of our study was PPH, which was defined as a blood loss of at least 500 mL within 24 hours postpartum. Moderate PPH was defined as blood loss between 500 and 999mL. Severe PPH was defined as blood loss of at least 1,000mL bleeding associated with hypotension (systolic blood pressure below 90 mmHg with a pulse rate higher than 90 beats per minute), or transfusion of at least three units of blood products based on the criteria of SurOSS.[22] The available independent variables (maternal, pregnancy, and delivery characteristics) were categorised according to international classifications (supplementary file 1). The criteria-based audit was confined to severe PPH. Prevention and management of severe PPH were audited using the national PPH guideline.[21,22] Detailed information on the cause, course, and management of severe PPH was not always available (supplementary file 2). This manuscript was written in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology Guidelines.[23]

Statistical analysis: Data were analysed using IBM SPSS version 24.0 (Armonk, New York, USA) and SAS v9.4 (SAS Institute, Gary Indiana). Frequencies of maternal, delivery, and perinatal characteristics were calculated in women with and without PPH. Logistic regression was used to investigate the independent association of risk indicators with moderate and severe PPH. Univariate regression analysis generated odds ratios (ORs) with 95% confidence interval (CI). The multivariable regression analysis included all variables with a p-value < 0.10 from the univariate analysis and variables reported by the literature as important risk indicators (e.g., multiple gestations, parity). These were presented as adjusted OR (aOR) with 95% confidence

interval (CI). A Pareto chart was used to prioritise areas for quality of care improvement, applying the "80-20 rule" of the Pareto principle, which suggests that most problems (80%) are due to a few key causes (20%).[24] Clinical management of PPH was reported as frequencies and percentages after applying the audit criteria. Pearson correlation was used to evaluate the association between blood loss, units of blood transfused, and ICU admission.

Ethical considerations: This research was performed according to the Declaration of Helsinki. The ethical review board of the Surinamese Committee on Research Involving Human Subjects approved the study on maternal morbidity on October 4th, 2016 (VG21-16) and the study on postpartum haemorrhage on September 8th, 2018 (VG11-18). The registry data was anonymous and aggregated, and the need for individual consent was waived.

RESULTS

Blood loss was documented in 96.4% (n=8747/9071) of the hospital deliveries in 2017 (table 1). The median blood loss of all included women who gave birth was 150 ml (range 0–4620). PPH occurred in 9.2% (n=808/8747) of the deliveries, with 6.7% (n=588/8747) being moderate and 2.5% (n=220/8747) severe PPH. The diagnosis of severe PPH was based on blood loss of more than 1,000 ml in 82.7% (n=182/220) of women, and in 17.3% (n=38/220) blood loss was moderate, but at least three units of blood products were transfused, or there was hemodynamic instability. In table 1, the maternal, perinatal and delivery characteristics of the births with and without PPH are compared. Pre-delivery anaemia occurred in 34.9% (n=65/186, missing 622) of women with PPH. Women of African descent were more frequently anaemic antepartum (63.0%, n=677/1074) than women from other ethnicities were (based on data availability of only two hospitals). The prevalence of PPH was higher in women delivered by caesarean section (CS) than those delivered by a vaginal birth (20.8%, n=400/1924 vs 6.0%, n=408/6823, respectively, $p < 0.01$). There were nine maternal deaths, three of which were complicated by PPH. Information on blood loss was most frequently missing in CS (65.7%,

n=213/324), low birth weight (29.1%, n= 94/324), and preterm births (25.7%, n=81/324) (table 1).

The prevalence of moderate and severe PPH in the hospitals varied significantly between 4.5 to 11.8% (p<0.001) and 1.3 to 4.0% (p<0.001), respectively, with the highest prevalence in Hospital D and the lowest in Hospital E (figure 1). CS prevalence was highest in Hospitals D (24.6%, n=604/2,456) and E (37.8%, n=564/1,493) and lowest in Hospital C (14.4%, n=53/367) (supplementary file 1). PPH after CS was more common in Hospital D than in other hospitals (48.4% vs 6.9–13.9%, p < 0.001). In Hospitals A, B, and D, women giving birth were more often of African descent (68.0% vs 51.8% vs 55.5%) compared to Hospitals C (5.8%) and E (26.6%). AMTSL (by administration of oxytocin for PPH prevention) was applied less frequently for severe PPH cases in Hospital D than in the other hospitals (46% (n=29/155) vs. 67.9–77.8%) (supplementary file 3).

Figure 1. Prevalence of PPH per hospital in Suriname, 2017

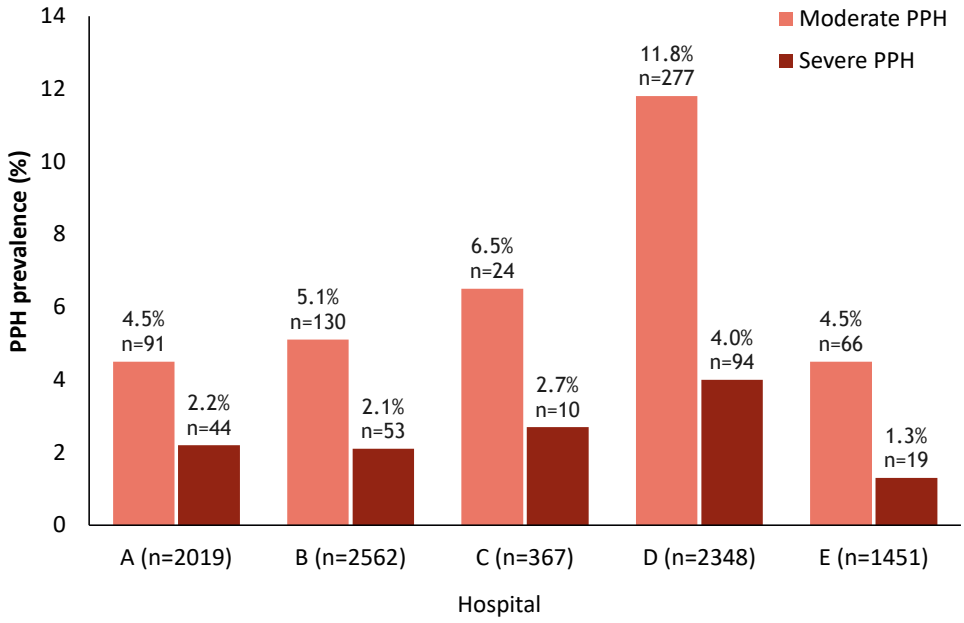


Table 1. Maternal, perinatal, and delivery characteristics of births in Suriname in 2017 with and without postpartum haemorrhage and undocumented blood loss

	No PPH	*Moderate*[1]	*Severe PPH*[2]	*Undocumented blood loss*
Total, n= (100%)	7939	588	220	324
Live births	7811 (98.4)	577 (98.1)	200 (91.9)	301 (92.9)
Stillbirths	128 (1.6)	11 (1.9)	20 (9.1)	23 (7.1)
Maternal characteristics				
Age (years)				
12–19	1164 (14.7)	64 (10.9)	24 (10.9)	37 (11.5)
20–34	5678 (71.6)	421 (71.6)	147 (66.8)	228 (70.8)
≥ 35	1087 (13.7)	103 (17.5)	49 (22.3)	57 (17.7)
Missing	*10*	*0*	*0*	*2*
Ethnicity				
Maroon	2271 (28.8)	151 (25.9)	80 (36.4)	82 (26.0)
Creole	1709 (21.7)	124 (21.2)	52 (23.6)	85 (27.0)
Hindustani	1469 (18.6)	88 (15.0)	27 (12.3)	71 (22.5)
Other[3]	1301 (16.5)	118 (20.2)	29 (13.2)	46 (14.6)
Javanese	835 (10.6)	76 (13)	21 (9.5)	22 (7.0)
Indigenous	295 (3.7)	27 (4.6)	11 (5.0)	9 (2.9)
Missing	*59*	*4*	*0*	*9*
Maternal HIV status				
Positive	58 (0.8)	5 (0.9)	2 (1.0)	3 (0.9)
Missing	*333*	*24*	*11*	*0*
Pregnancy characteristics				
Parity				
0	2729 (34.5)	205 (35)	65 (29.5)	113 (36.1)
1–4	4579 (57.8)	334 (57)	125 (56.8)	174 (55.6)
≥ 5	612 (7.7)	47 (8)	30 (13.6)	26 (8.3)
Missing	*19*	*2*	*0*	*11*
Gestational age				
< 32 weeks	231 (2.9)	12 (2)	17 (7.8)	34 (10.8)
32–36 weeks	806 (10.2)	79 (13.5)	45 (20.5)	47 (14.9)
≥ 37 weeks	6863(86.4)	495 (84.5)	157 (71.7)	234 (74.3)
Missing	*39*	*2*	*1*	*9*
Anaemia[4]	990 (37.6)	46 (34.3)	19 (36.5)	30 (36.6)
Missing	*5307*	*454*	*168*	*242*
Multiple pregnancy	88 (1.1)	9 (1.5)	10 (4.5)	9 (2.8)

Table 1. Continued

	No PPH	*Moderate[1]*	*Severe PPH[2]*	*Undocumented blood loss*
Delivery characteristics				
Hospital of delivery				
A	1884 (23.7)	91 (15.5)	44 (20.0)	82 (25.3)
B	2379 (30.0)	130 (22.1)	53 (24.1)	92 (28.4)
C	333 (4.2)	24 (4.1)	10 (4.5)	24 (4.1)
D	1977 (24.9)	277 (47.1)	94 (42.7)	108 (33.3)
E	1366 (17.2)	66 (11.2)	19 (8.6)	42 (13.0)
Onset of labour				
Augmentation	1771 (47.4)	86 (45.7)	38 (48.1)	32 (33.0)
Missing	*4202*	*400*	*141*	*227*
Mode of delivery				
Spontaneous	689 (79.2)	267 (45.4)	127 (57.7)	107 (33)
Caesarean section	1524 (19.2)	311 (52.9)	89 (40.5)	213 (65.7)
Instrumental	126 (1.6)	10 (1.7)	4 (1.8)	4 (1.2)
Vaginal laceration				
2nd grade or higher	1644 (50.6)	86 (55.8)	26 (41.9)	19 (29.7)
Missing	*4961*	*434*	*158*	*260*
Birth weight (grams)				
< 2,500	1115 (14.1)	69 (11.7)	48 (22.2)	94 (29.1)
2,500–3,999	6582 (83.2)	483 (82.6)	154 (71.3)	219 (67.8)
≥ 4,000	211 (2.7)	33 (5.6)	14 (6.5)	10 (3.1)
Missing	*31*	*3*	*4*	*1*

Legend [1]Blood loss 500–999mL; [2]Blood loss ≥1000mL or blood loss <1000mL with hemodynamic instability or ≥ 3 units blood transfusion**;** [3]Ethnicity other: Mixed, Chinese, Brazilian, Caucasian, or unknown; [4] Haemoglobin ≤ 100 g/L or ≤6.1 mmol/L

The logistic regression analysis for moderate and severe PPH is presented in table 2. Women of Creole and Maroon ethnicity had significantly higher odds of developing severe PPH than Hindustani women did (aOR 1.8, 95% CI 1.1–3.0 vs 2.1, 95% CI 1.3–3.3, respectively). Women delivering in Hospital D were more likely to experience moderate (aOR 2.7, 95% CI 2.2–3.4) and severe PPH (aOR 2.4, 95% CI 1.7–3.4) compared to Hospital B. Also, the risk of both moderate and severe PPH was significantly higher in women delivering by CS (aOR 5.4, 95% CI 4.5–6.6 vs aOR 3.9, 95% CI 2.9–5.3) compared to vaginal delivery.

Table 2. Univariate and multivariate logistic regression for moderate and severe postpartum haemorrhage (PPH)

	Moderate PPH[1]		Severe PPH[2]	
	cOR (95% CI)	**aOR[3] (95% CI)**	**cOR (95% CI)**	**aOR[3] (95% CI)**
		p = 0.003	p < 0.001	p < 0.001
Live birth	Reference	Reference	Reference	Reference
Stillbirth	1.2 (0.6–2.2)	**2.9 (1.4–6.0)**	**6.1 (3.7–10.0)**	**6.4 (3.4–12.2)**
Maternal characteristics				
Age (years)	p = 0.004		p = 0.001	
12–19	0.7 (0.6–1.0)	0.8 (0.6–1.1)	0.8 (0.5–1.2)	0.8 (0.5–1.3)
20–34	Reference	Reference	Reference	Reference
≥ 35	**1.3 (1.2–1.7)**	1.1 (0.9–1.4)	**1.7 (1.3–2.4)**	1.4 (0.9–2.0)
Ethnicity	p = 0.02	p = 0.001	p = 0.04	p = 0.07
Maroon	1.1 (0.9–1.5)	**1.5 (1.1–2.0)**	**1.9 (1.2–3.0)**	**2.1 (1.3–3.3)**
Creole	1.2 (0.9–1.6)	**1.5 (1.1–2.0)**	1.7 (1.0–2.7)	**1.8 (1.1–3.0)**
Hindustani	Reference	Reference	Reference	Reference
Other[4]	1.5 (1.1–2.0)	**1.8 (1.3–2.4)**	1.2 (0.7–2.1)	1.3 (0.8–2.3)
Javanese	1.5 (1.1–2.1)	**2.0 (1.4–2.8)**	1.4 (0.8–2.4)	1.9 (1.0–3.4)
Indigenous	1.5 (1.0–2.4)	1.5 (0.9–2.5)	2.0 (1.0–4.1)	2.0 (0.9–4.1)
HIV status				
Positive	1.2 (0.5–2.9)		1.3 (0.3–5.2)	
Negative	Reference		Reference	
Pregnancy characteristics				
Parity			p = 0.005	
0	1.0 (0.7–1.2)	1.1 (0.9–1.3)	0.9 (0.6–1.2)	1.1 (0.8–1.5)
1–4	Reference	Reference	Reference	Reference
≥ 5	1.1 (0.8–1.5)	1.1 (0.8–1.6)	**1.8 (1.2–2.7)**	1.2 (0.8–1.9)
Gestational age	p = 0.03	p = 0.05	p < 0.001	p = 0.004
< 32 weeks	0.7 (0.4–1.3)	1.2 (0.6–2.4)	**3.2 (1.9–5.4)**	**2.3 (1.1–4.9)**
32–36 weeks	**1.4 (1.1–1.7)**	**1.5 (1.1–2.0)**	**2.4 (1.7–3.4)**	**2.1 (1.3–3.2)**
≥ 37 weeks	Reference	Reference	Reference	Reference
Antepartum anaemia				
No anaemia	Reference		Reference	
Anaemia[5]	0.9 (0.6–1.3)		1.0 (0.5–1.8)	
Type of pregnancy			p < 0.001	p < 0.001
Singleton	Reference	Reference	Reference	Reference
Multiple	1.4 (0.7–2.8)	1.4 (0.6–3.0)	**4.3 (2.2–8.3)**	**3.4 (1.7–7.1)**

Table 2. Continued

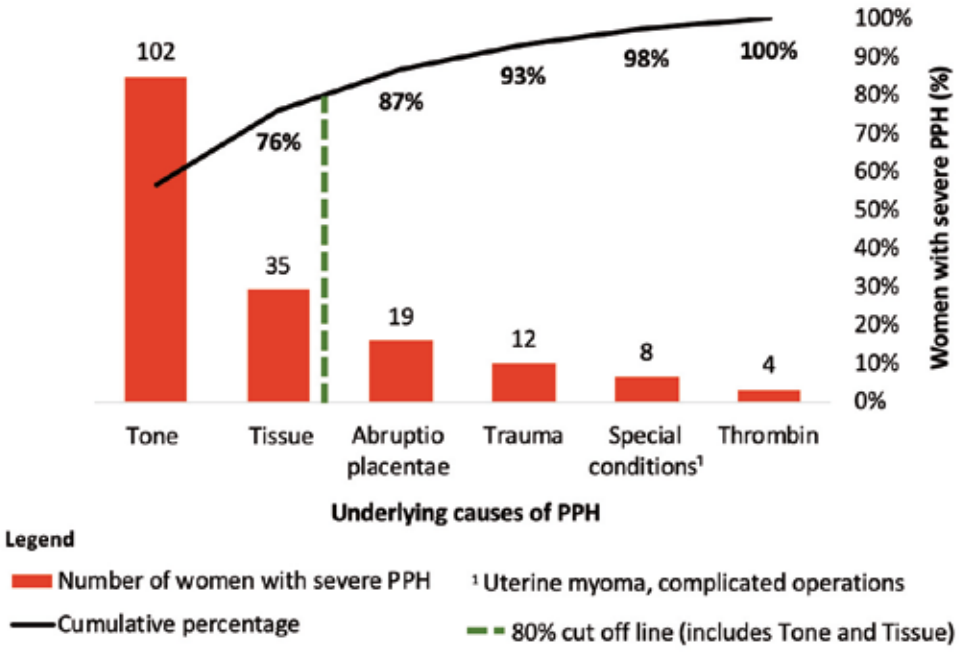
	Moderate PPH[1]		Severe PPH[2]	
	cOR (95% CI)	aOR[3] (95% CI)	cOR (95% CI)	aOR[3] (95% CI)
Delivery characteristics				
Hospitals	p < 0.001	p < 0.001	p < 0.001	p < 0.001
A	0.9 (0.7–1.2)	1.0 (0.7–1.3)	1.1 (0.7–1.6)	1.0 (0.6–1.5)
B	Reference	Reference	Reference	Reference
C	1.3 (0.8–2.1)	1.7 (1.0–2.8)	1.4 (0.7–2.7)	2.1 (1.0–4.4)
D	**2.6 (2.1–3.2)**	**2.7 (2.2–3.4)**	**2.1 (1.5–3.0)**	**2.4 (1.7–3.4)**
E	0.9 (0.7–1.2)	0.6 (0.4–0.8)	0.6 (0.4–1.1)	0.5 (0.3–0.9)
Onset of labour				
Spontaneous	Reference		Reference	
Augmentation	0.9 (0.7–1.3)		1.0 (0.7–1.6)	
Mode of delivery	p < 0.001	p < 0.001	p < 0.001	
Spontaneous	Reference	Reference	Reference	Reference
Instrumental	1.9 (1.0–3.6)	**2.1 (1.1–4.1)**	1.6 (0.6–4.3)	2.1 (0.9–6.1)
Caesarean section	**4.8 (4.0–5.7)**	**5.4 (4.5–6.6)**	**2.9 (2.2–3.8)**	**3.9 (2.9–5.3)**
Vaginal laceration				
None or 1st grade	Reference		Reference	
2nd grade or higher	0.8 (0.6–1.1)		1.4 (0.9–2.4)	
Birth weight (grams)	p < 0.001	p < 0.001	p < 0.001	p = 0.001
< 2500	0.8 (0.7–1.1)	0.2 (0.4–0.9)	**1.8 (1.3–2.6)**	0.7 (0.4–1.1)
2500–3999	Reference	Reference	Reference	Reference
≥ 4000	**2.1 (1.5–3.1)**	**1.9 (1.3–2.9)**	**2.8 (1.6–5.0)**	**2.8 (1.5–5.0)**

Legend [1]Blood loss 500–999 mL; [2]Blood loss ≥1000mL, or blood loss <1000mL with hemodynamic instability or ≥3 units blood transfusion; [3]Adjusted: multivariate analysis of risk factors with p < 0.10 in univariate analysis and a priori risk factors (multiple gestations, parity); [4] Ethnicity other: mixed, Chinese, Brazilian, Caucasian, or unknown; [5]Haemoglobin ≤ 100 g/L or 6.1 mmol/L

Other strongly associated risk indicators for severe PPH were stillbirths (aOR 6.4, 95% CI 3.4–12.2), multiple pregnancy (aOR 3.4, 95% CI 1.7–7.1), very preterm birth (aOR 2.3, 95% CI 1.1–4.9), preterm birth (aOR 2.1, 95% CI 1.3–3.2), and neonatal macrosomia (aOR 2.8, 95% CI 1.5–5.0). At least one risk indicator was present in 70.1% (n=6130/8747) of the births without PPH and in 80.8% (n=653/808) of births complicated by PPH.

The Pareto chart shows that uterine atony (56.7%, n=102/180, missing 40) and retained placenta (19.4%, n=35/180, missing 40) caused almost 80% of severe PPH (figure 2). Severe PPH occurred among women with preeclampsia in 23.2% (n=45/194, missing 26) and eclampsia in 2.6% (n=5/194) of cases. Of the women with severe PPH, 17.1% (n= 33/193, missing 27) were admitted to the ICU. Among women with a CS and severe PPH (n=89), the CS was considered elective for 53.9% (n=48), emergency for 32.6% (n=29), and unclassified for 13% (n=12). Women with severe PPH had a stillbirth in 9.1% of cases (n=20/220) in contrast to 1.6% (n=128/7939) stillbirth prevalence in women without PPH. Women with severe PPH and stillbirth were often diagnosed with placental abruption (85%, n=17/20) [concomitant pre-eclampsia existed in 70.6% (n=12/17) of women with placental abruption].

Figure 2. Pareto chart of the specific underlying causes of PPH in Suriname, 2017



The management of PPH was evaluated using the criteria of the national guideline (figure 3). AMTSL by administering oxytocin immediately after delivery was applied in 61.3% (n= 95/155, missing 65) of women with severe PPH. When a CS was performed, fewer women (55.3%, n= 26/47, missing 42) received prophylactic oxytocin compared to vaginal births (65.1%, n= 69/106, missing 25). Two of the three cases of severe PPH received oxytocin treatment (68.8%, n= 106/154, missing 66). Tranexamic acid was administered to 4.9% (n= 5/103, missing 117) of women with severe PPH. While five women with blood loss below 1 litre received 6 to 10 units of blood products, eight women with blood loss ≥1500 ml (17.4%, n= 46) received no blood products. These eight women had haemoglobin levels of at least 100 g/l and were hemodynamically stable. Blood loss was weakly to moderately correlated with the number of blood units transfused (Pearson's coefficient 0.47, $p< 0.01$) but not with ICU admission (Pearson's coefficient 0.05, $p=0.46$).

DISCUSSION

Based on national registry data in 2017, the prevalence rates of PPH and severe PPH in Suriname were 9.2% and 2.5%, respectively, with substantial variation across the different hospitals. Risk indicators associated with severe PPH were (1) being of African descent, (2) having a multiple pregnancy, (3) delivery in Hospital D, (4) CS, (5) stillbirth, (6) preterm birth, and (7) macrosomia. At least one risk indicator was present in 80% of women with PPH but also in 70.1% of those without PPH. Severe PPH was mainly due to uterine atony and retained placental tissue. The criteria-based audit identified inadequate administration of oxytocin for PPH prevention (AMTSL) and therapy and infrequent use of tranexamic acid for treatment. While CS was a major risk factor, fewer women who delivered by CS received prophylactic oxytocin than women delivering vaginally did. Worldwide and in Latin America and the Caribbean (including Suriname), PPH was the most frequent direct underlying cause of maternal deaths in 2010.[1,18]

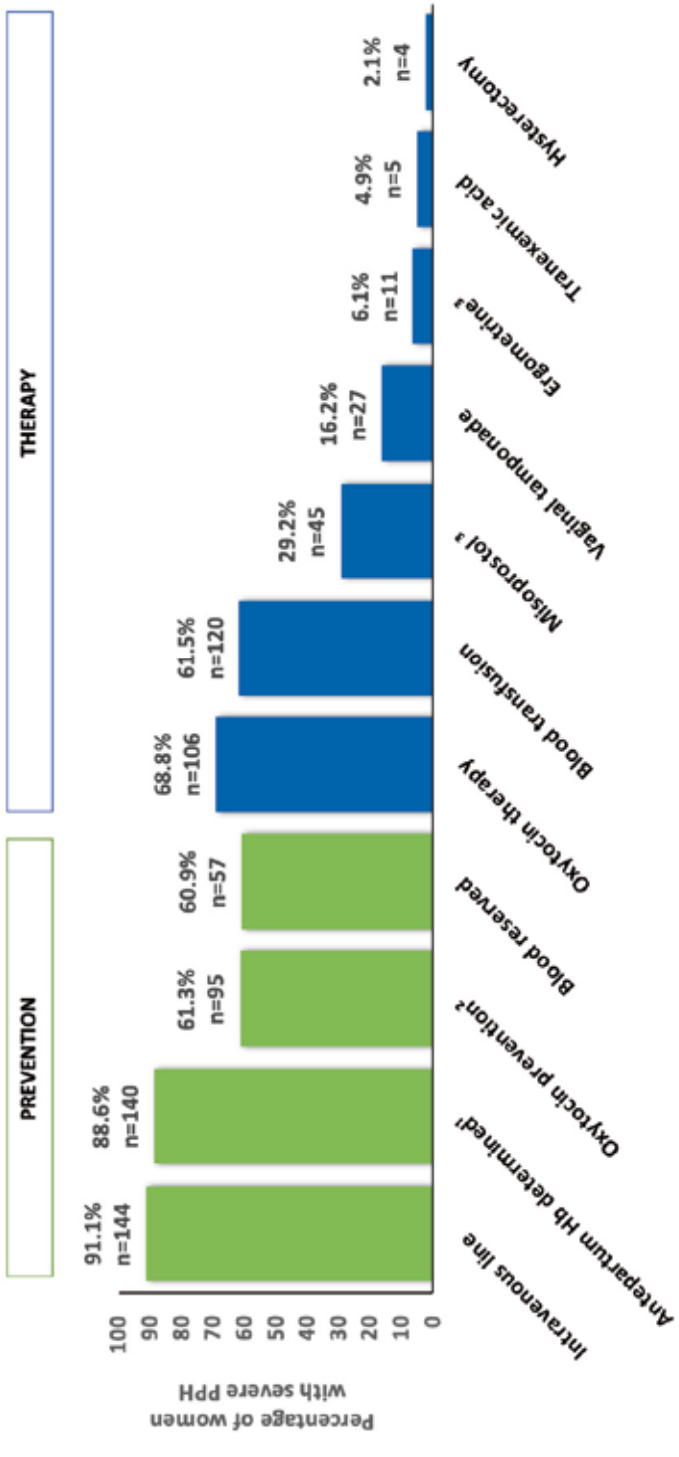


Figure 3. Criteria-based audit of the management of severe PPH in Suriname, 2017, conform national standards (guidelines)

Legend [1] Recent antepartum haemoglobin (Hb) level determined; [2] Oxytocin prevention, defined as active management of the third stage of labor (AMTSL); [3] Misoprostol a synthetic prostaglandin analog and ergometrine is a potent uterotonic drug

To reduce preventable maternal mortality from PPH in the Americas the Pan-American Health Organization (PAHO) and its Latin American Centre for Perinatology, Women and Reproductive Health launched the "Zero Maternal Mortality from Haemorrhage" initiative in 2015.[2] Following the designation of Suriname as one of 10 priority countries for reducing maternal mortality, PAHO implemented this project in Suriname in 2018.[25] In Suriname, efforts to reduce preventable maternal deaths from PPH resulted in national PPH guideline development and obstetric emergency training in 2016 and 2019.[27]

The prevalence of (severe) PPH in Suriname in this study was consistent with global and regional prevalence.[10,11] Interhospital prevalence varied significantly despite the close geographic vicinity of four hospitals in the capital city. One explanation for this variation could be the differences in maternal, perinatal, and delivery characteristics among the hospitals as reported in this study. In Hospital D, for example, PPH prevalence was the highest, with the second-highest CS rate and higher prevalence of preterm delivery and multiparity. Another explanation for the varied interhospital PPH prevalence was the inconsistent and subjective way of obtaining information on blood loss postpartum as described in the methods of this study.[21] Subjective determination of the quantity of blood loss was inaccurate since blood loss was often underestimated at large volumes and overestimated at lower volumes.[17,21,27] The inaccurate estimation could also explain the weak or moderate correlation between blood loss volume and PPH severity in this study. Finally, interhospital differences in PPH could result from the unequal availability of or adherence to local and national protocols and consequently, different PPH management.[21] For example, AMTSL for PPH prevention was applied less frequently in Hospital D (studied only for severe PPH). We, therefore, recommend consistent and accurate blood loss quantification and adherence to PPH national guidelines.

The risk indicators found in this study (ethnicity, premature delivery, stillbirth, multiple gestations, CS, and macrosomia) were congruent with those reported elsewhere.[27,29-31] African descendants have higher risks of developing PPH compared to women of other ethnicities.[32-34] Additionally, women of African origin

were more commonly anaemic antepartum[28], putting them at higher risk of adverse clinical outcome when PPH develops.[17] Our study shows that women with higher antepartum haemoglobin levels stayed hemodynamically stable despite severe blood loss. This highlights the importance of prevention and treatment of antenatal anaemia by routine iron and folate supplementation, especially in women of African descent.[21,35]

We found a strong association between severe PPH and stillbirths, which is most likely attributable to a high frequency of placental abruption among these women. A recent stillbirth study in Suriname (2016–2017) reported that placental abruption contributed to 23% of stillbirths.[36] This indicates that placental abruption and maternal conditions such as preeclampsia could be confounders in the association of stillbirth with PPH. As such, improved management of preeclampsia should reduce the risk of PPH from placental abruption. Most healthcare workers were familiar with grand multiparity as a risk indicator and anticipated accordingly, which may explain the non-significant result found in our study. At least one risk indicator was present in most deliveries complicated by PPH but also in two thirds of uncomplicated pregnancies without PPH. This weak discriminative ability of risk indicators to identify women who could develop PPH was also reported elsewhere.[12,14,15] Therefore, although risk indicator analysis should be considered to anticipate PPH occurrence, PPH can occur unforeseen, and other approaches are also needed for appropriate management.

Extrapolating the Pareto principle to our study (the "80-20 rule"), a focus on prevention of uterine atony and retained placental tissue could significantly reduce severe PPH. In AMTSL, the best preventive measure for PPH was the administration of uterotonics (oxytocin) immediately after every birth.[8,37] The criteria-based audit showed inadequate use of prophylactic oxytocin in severe PPH, especially among women delivering by CS. In contrast, according to previous interviews with healthcare providers in Suriname AMTSL was applied in all births by CS.[21] This indicates that AMTSL was not yet routine practice in Suriname in 2017 despite advice from World Health Organization (WHO) and national guidelines.[8,21] Tranexamic acid is an antifibrinolytic agent widely used to prevent and treat

haemorrhages.[38,39] While sporadically used to treat severe PPH in Suriname in 2017, it is now routine practice in the first response to PPH.[38] In 2017, the WHO updated the PPH guidelines by adding the use of tranexamic acid in early PPH as advised by the World Maternal Antifibrinolytic (WOMAN) trial, which was a large multi-country randomised control trial.[40,41] We recommend the application of AMTSL in every delivery and integration of tranexamic acid as a component of the primary treatment of PPH consistent with recent international guidelines.[38,41]

Strengths and limitations

The strengths of this study included its national coverage. Information was obtained on the prevalence of PPH in Suriname for the first time by incorporating routinely available information from the parturition book. Application of the criteria-based audit based on national guidelines allowed for in-depth analysis of specific gaps in care to guide the prioritization of actions to reduce PPH.

This study had several limitations. First, parturition books only include facility-based deliveries or postpartum referrals, and the inclusion of primary care and home births could have resulted in lower PPH prevalence rates since the 14% primary care and home births were excluded from the analysis. The second limitation was the higher percentage of missing data for women who delivered by CS or preterm, which are two significant risk indicators for PPH.

The third limitation is that only postpartum haemorrhage was evaluated, while obstetric haemorrhage leading to mortality and severe morbidity could also result from antepartum, post-abortion, and late miscarriages. The fourth limitation was that several known risk factors (such as socioeconomic status, body mass index, medical history, complications in the current pregnancy, anaemia, CS indication, and labour duration) could not be included in the regression analysis since these data were not available. This may explain certain observations, such as why Hospital E with the highest CS prevalence had the lowest prevalence of PPH. Finally, missing information on the causes and management of PPH impacted the criteria-based audit analysis, such as undocumented information on PPH prevention (AMTSL) among births without PPH.

CONCLUSION

Although PPH prevalence and risk indicators for Suriname are consistent with global and regional figures, wide interhospital variations exist. Since uterine atony and retained placenta are associated with almost 80% of severe PPH, intervention efforts should focus on adequate prevention, anticipation, early recognition, and prompt treatment. PPH in Suriname can be reduced by 1) prevention of PPH by applying AMTSL in every delivery and anticipating risk factors, 2) early recognition of PPH by precisely and consistently measuring blood loss, and 3) adequate therapy conforming to national guidelines. Accurate, relevant, and comprehensive data collection is essential to identify specific risk indicators and evaluate guideline implementation in the future. To gain precise insight into the gaps in PPH management, we suggest that countries focus on disaggregated data analysis and criteria-based audits.

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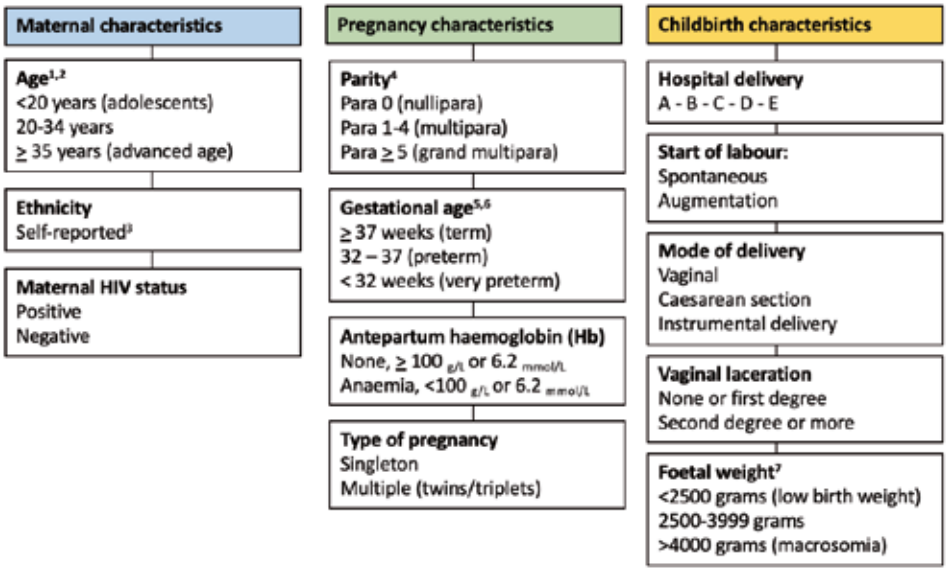
Supplementary file 1. Categories of available maternal characteristics, pregnancy and delivery outcomes based on international classification.



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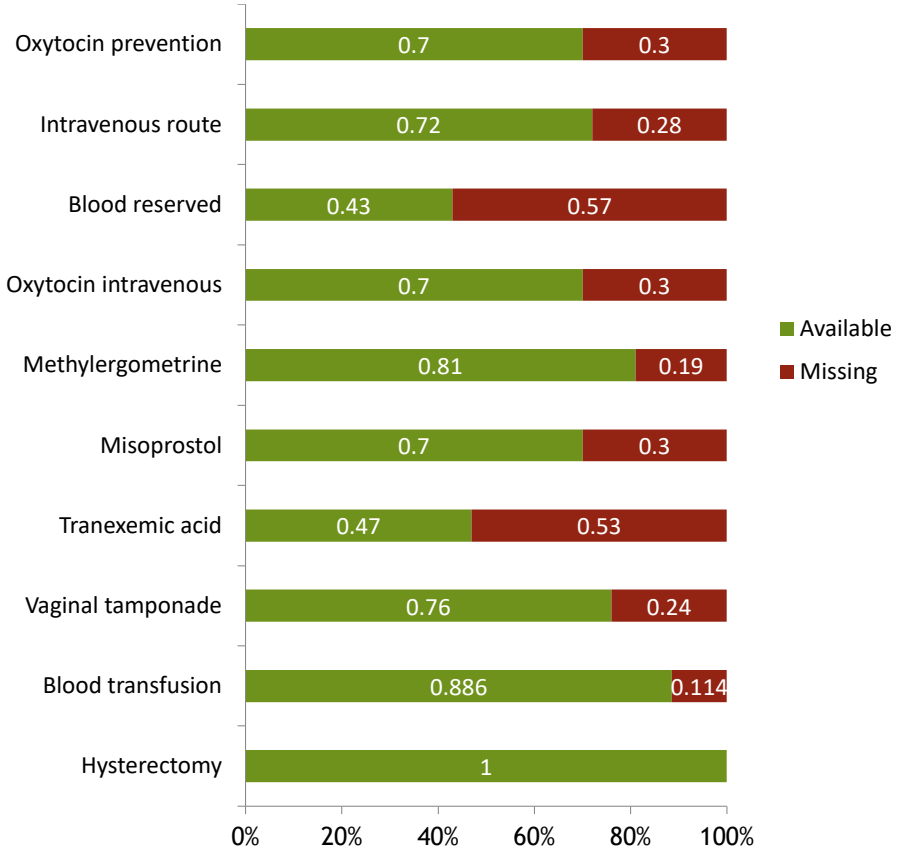
Supplementary file 2. Availability of data on causes and management of postpartum haemorrhage (PPH) to perform a criteria-based audit.



Supplementary file 3. Maternal and perinatal characteristics of the hospital deliveries in Suriname in 2017

Hospital	A	B	C	D	E
Total n (100%)	**2101**	**2654**	**367**	**2456**	**1493**
Live births	2018 (96.0)	2616(98.6)	361 (98.4)	2416 (98.4)	1478 (99.0)
Stillbirths	83 (4.0)	38 (1.4)	6 (1.6)	40 (1.6)	15 (1.0)
Maternal Characteristics					
Age (years)					
12 – 19	382 (18.2)	355 (13.4)	67 (18.3)	384 (15.7)	101(6.8)
20 - 34	1465 (69.9)	1851 (69.8)	264 (71.9)	1724 (70.4)	1170 (78.4)
≥ 35	250 (11.9)	447 (16.8)	36 (9.8)	342 (14)	221 (14.8)
Missing	4	1	0	6	1
Ethnicity					
Maroon	863 (41.8)	785 (29.6)	2 (0.6)	844 (34.4)	90 (6.1)
Creole	541 (26.2)	589 (22.2)	18 (5.2)	517 (21.1)	305 (20.5)
Hindustani	328 (15.9)	477 (18.0)	196 (56.6)	382 (15.6)	272 (18.3)
Other[1]	155 (7.5)	381 (14.4)	66 (19.1)	394 (16.0)	498 (33.5)
Javanese	102 (4.9)	324 (12.2)	40 (11.6)	198 (8.1)	290 (19.5)
Indigenous	74 (3.6)	93 (3.5)	24 (6.9)	120 (4.9)	31 (2.1)
Missing	*38*	*5*	*21*	*1*	*7*
Maternal HIV status					
Positive	39 (1.9)	14 (0.5)	N/A	1 (0)	14 (0.9)
Missing	*1*	*0*		*1*	*0*
Pregnancy characteristics					
Parity					
0	601 (28.7)	1000 (38.0)	147 (40.2)	721 (29.4)	643 (43.1)
1 – 4	1265 (60.4)	1423 (54.0)	206 (56.3)	1495 (60.9)	823 (55.2)
≥ 5	227 (10.8)	210 (8.0)	13 (3.6)	240 (9.8)	25 (1.7)
Missing	*8*	*21*	*1*	*0*	*2*
Anaemia[2]	731 (50.4)	N/A	N/A	N/A	347 (24.2)
Missing	*652*				*58*
Twin / triplet	30 (1.4)	41 (1.5)	1 (0.3)	29 (1.2)	15 (1)

Supplementary file 3. Continued

Hospital	A	B	C	D	E
Delivery characteristics					
Onset of labour					
Augmentation	781 (37.2)	781 (37.2)	101 (27.5)	N/A	445 (34.2)
Missing	*1*	*2054*	*266*		*193*
Mode of delivery					
Spontaneous	1725 (82.1)	2026 (76.3)	285 (77.7)	1827 (74.4)	927 (62.1)
Caesarean Section	364 (17.3)	552 (20.8)	53 (14.4)	604 (24.6)	564 (37.8)
Instrumental	12 (0.6)	76 (2.9)	29 (7.9)	25 (1.0)	2 (0.1)
AMTSL [3] only for severe PPH n=155 (100%)					
Oxytocin prevention	19 (67.9)	30 (75.0)	7 (77.8)	29 (46.0)	11 (73.3)
Missing	*16*	*13*	*1*	*31*	*4*
Vaginal laceration					
2nd grade or higher	434 (27.8)	771 (72.7)	101 (95.3)	N/A	469 (58.6)
Missing	541	1593	261		1692
Birthweight (grams)					
< 2500	435 (20.9)	318 (12.0)	55 (15.1)	354 (14.4)	164 (11.0)
2500 – 3999	1599 (76.7)	2234 (84.6)	293 (80.3)	2054 (83.7)	1258 (84.6)
≥ 4000	52 (2.5)	88 (3.3)	17 (4.7)	46 (1.9)	65 (4.4)
Missing	*15*	*14*	*2*	*2*	*6*

Legend [1]Ethnicity other: Mixed, Chinese, Brazilian, Caucasian, unknown; [2]Haemoglobin ≤ 100 g/l or 6.1 mmol/l; [3] AMTSL: Active Management of the Third Stage of Labour; N/A = not available

Trends in maternal mortality in Suriname: comparing three confidential enquiries in three decades

8

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ABSTRACT

Background

Confidential enquiries into maternal deaths (CEMD) are crucial to investigate disparities in maternal mortality ratio (MMR) between and within countries. We aim to study the trend in MMR, causes, delay and "lessons learned" in Suriname, over three decades with three CEMD and provide recommendations.

Methods

A national CEMD (CEMD-III) was conducted between 2015-2019 by a prospective, population-based surveillance and multidisciplinary systematic maternal death review. Subsequently, we compared the results with previous CEMD [CEMD-I (1991-1993) and CEMD-II (2010-2014)].

Results

We identified 62 maternal deaths in CEMD-III (MMR 127/100.000 livebirths). Of the deceased women, 23%(n=14/62) were in poor condition when entering a health facility, while 18%(n=11/62) died at home or during transportation.

The MMR declined over the years. In all three CEMD most women were of African-descent, died postpartum and in the hospital. Significantly more women were uninsured in CEMD-III (25%(n=15/59)) compared to CEMD-II (0%) and CEMD-I (9%(n=6/64)). Obstetric haemorrhage was less often the underlying death cause. Maternal deaths were preventable in nearly half of the cases in CEMD-II (n=28/65) and CEMD-III (n=29/62).

Conclusions

Suriname's MMR declined too slowly in 30 years. Preventable maternal deaths should be eliminated by ensuring universal access to high-quality facility-based birthcare, especially for vulnerable women .

BACKGROUND

Ending preventable maternal death remains at the top of the global health agenda.[1,2] Still, in 2017 approximately 300.000 women died globally because of pregnancy-related complications (3). Maternal mortality ratio (MMR) varied widely among countries; most deaths (95%) occurred in Low- and Middle income Countries (LMIC) and were preventable.[3-5] This disparity in MMR between, but also within, countries relates to the progression of the country's socioeconomic development and improvement in health care resulting in health inequity (differences in access to and availability of care), and inequality (differences in quality of care).[6-8] Confidential enquiries into maternal deaths (CEMD) can provide insight into such disparities, and comprise the multidisciplinary and systematic investigation of the causes and circumstances surrounding the death and identification of the "lessons learned".[9,10] CEMD could be carried out at the regional or national level and include facility- and community-based maternal deaths reviews (MDR). Recommendations are provided on every (community, facility and governmental) level and aspect of health care to avert preventable maternal deaths.[7,11] The WHO recommends that MDR combined with the development of local leadership and training should be conducted in all hospitals globally and operational research is needed on the most (cost)effective ways to implement these MDR in LMIC.[12] However, monitoring the implementation of recommendations and responses, and measuring the impact remains extremely challenging, especially in LMIC where the need is highest.[13]

In the middle income, South American country, Suriname, systematic prospective national multidisciplinary MDR were implemented since 2015 in a nationwide effort to reduce MMR.[14] Two individual CEMD were conducted previously: one prospectively from 1991 - 1993 (CEMD-I), and one retrospective analysis of cases between 2010 - 2014 (CEMD-II).[15,16] Quality of care improvements since 2015 were driven by recommendations from CEMD-II and included the establishment of the committee Maternal Mortality Suriname (MaMS) to perform systematically and multidisciplinary maternal death reviews, and the development of national guidelines combined with obstetric emergency training.[14,17]

We aim to study the trend in prevalence, causes, delay and "lessons learned" in maternal mortality in Suriname over almost three decades with three CEMD, and provide recommendations to decrease preventable maternal deaths in Suriname.

METHODS

Study design

First, we conducted a population-based prospective confidential enquiry (CEMD-III) from January 2015 to December 2019. Pregnancy-related deaths were reviewed by the national review committee MaMS. Subsequently, a comparative analysis with two previous CEMD (1991 - 1993 and 2010 - 2014) was performed.

Study setting

Suriname is a middle-income country in South America. Its population was 583.200 in 2017.[18] After the deteriorated economic situation in the nineties, there was economic growth between 2004 and 2012 with an increase of Gross Domestic Product (GDP) of 4% per year.[19,20] Since 2015 however, the country's financial recession impedes development plans to decrease social inequalities.[21] Of the 10.000 births each year in Suriname 86% take place in hospitals, 6% at primary care clinics (3% in the rural interior and 3% rural coastal), 4% at homes and 4% at unknown locations.[15,22] Women with complicated pregnancies and deliveries in primary care clinics are referred to hospitals. The ethnic distribution among the women who gave birth in 2016 and 2017 was: Maroon (28%), Creole (23%), Hindustani (19%), Javanese (11%), Mixed (12%), Indigenous (4%), Chinese and Other (3%).[22] Over the years, the Maroon population in general increased by 62%.[23,24] Also, the percentage of Maroon women living in urban areas increased by 10%.[23]

The health system in Suriname is a public-private mix, with different financing modalities and service providing facilities.[24,25] Until 2014 the insurance system in Suriname was either private (13%) or public (21% insured at the State Health Foundation [SZF], primarily intended for civil servants and 6% at “Medical Mission”, for those living in the rural interior). Additionally, poor and disadvantaged people received social insurance coverage (44%) from the Ministry of Social Affairs.[15,24] The

remaining population (16%) had an unknown insurance status.[24] In 2014, steps toward universal health coverage and equity in health were made by enforcing the Basic Health Law.[21] To eliminate disparity in care due to insurance status, social insurance was terminated, and the government covered the insurance of the before mentioned people by insuring them at SZF.[24] However, there were issues with the implementation of this law resulting in barriers to receive such insurance and, consequently, people stayed uninsured.[26]

Data collection

In CEMD-I the data collection was performed prospectively from 1991 - 1993 and the methods used were 1) notification of maternal death by health care workers in hospitals, primary care and mortuary, 2) a hospital-based Reproductive Age Mortality Survey (RAMoS), which included the screening of all deceased women of reproductive age for (recent) pregnancy and 3) a RAMoS of the national Register of Causes of Death, located at the Bureau of Public Health (BOG, its Dutch acronym).[27] A maternal mortality expert committee, (seven obstetricians and one midwife) confidentially reviewed all case summaries.

In 2015, maternal deaths from 2010 - 2014 were retrospectively collected (CEMD-II) by 1) conducting a RAMoS in the hospitals and primary care, 2) data cross-link with Central Bureau for Civil Affairs (CBB) and vital registration (BOG) and, 3) performing a mortuary inventory. Maternal deaths were reviewed by an expert committee in which obstetricians, midwives, internal medicine specialists, or anaesthesiologists participated, and cases were classified using the WHO International Classification of Diseases-Maternal Mortality (ICD-MM).[15,28]

In CEMD-III maternal deaths were notified by involved health care providers and by vital registration. Various sources were used to identify possible maternal deaths that were not reported: 1) CBB provided a list of all deceased women of reproductive age (15 - 49 years), including those who died within one year after giving birth and, 2) a RAMoS was performed of hospital deaths (of which the medical files could be retrieved). The committee MaMS was installed in 2015 and reviewed any possible maternal death systematically.[14] The committee consists of

four gynaecologists/obstetricians, one midwife, one internal medicine specialist, one BOG representative, two medical students, and several external consultants.[29] Similar to the previous enquiries, classification of maternal deaths was in accordance with WHO ICD-MM.[28]

Definitions

We defined pregnancy-related, maternal, direct, indirect and unspecified maternal death in accordance with the WHO ICD-MM.[28] A pregnancy-related death is the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the cause of death. Maternal death is a pregnancy-related death from any cause related to or aggravated by the pregnancy or its management, but not from accidental or incidental causes.[30] The maternal mortality ratio (MMR) is the ratio of maternal deaths to live births (calculated per 100.000 live births).[30] A direct maternal death is caused by direct obstetric causes. An indirect death results from a previous existing disease or a disease that developed during pregnancy and which is not due to direct obstetric causes, but aggravated by the physiologic effects of pregnancy.[31] Maternal deaths are classified as "unspecified" when the underlying cause was unknown or not determined.[28] Late maternal deaths occur after 42 days, but within one year following delivery from causes directly related to pregnancy or indirectly precipitated by the effects of pregnancy on underlying diseases; coincidental deaths are not included.[28,32] Advanced maternal age is defined as 35 years, or older.[33] Substandard care was defined as a deviation from standard practice according to local clinicians and international guidelines.

Data analysis

Data on demographics, general and obstetric history, and committee consensus classification were manually entered in IBM SPSS version 24.0 (Armonk, New York, USA). Descriptive analysis was used to calculate frequencies and proportions. The significance of the differences between the categorical variables (characteristics) was calculated using the chi-square test, with a significance level below 0.05. Cases were categorised using the WHO ICD-MM groups of underlying causes.[28]

Substandard care was analysed by the review committee, according to the model of three delays that contribute to maternal mortality namely 1) phase I delay - delay in the decision to seek care, 2) phase II delay - delay in reaching a health care facility, and 3) phase III delay - delay in receiving adequate and appropriate care at the facility.[34] This manuscript was written in accordance with "The Strengthening the Reporting of Observational Studies in Epidemiology Guidelines".[35]

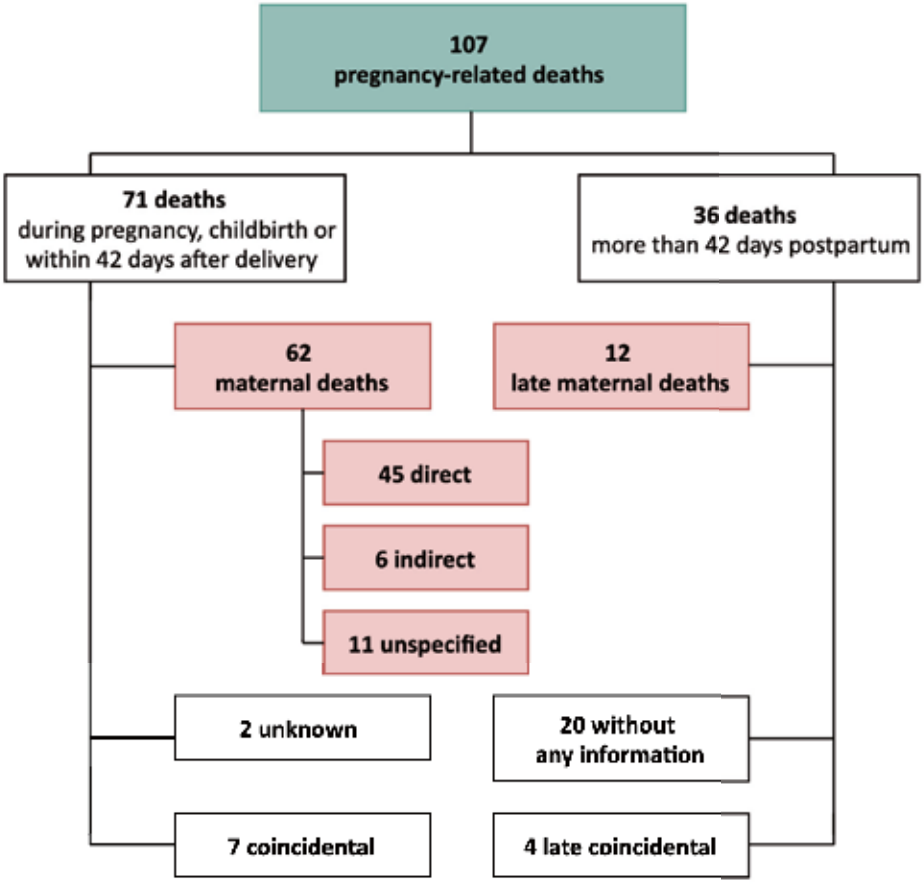
Ethical considerations

This research was performed according to the Declaration of Helsinki and has been approved by the ethical review board of the Surinamese Committee on Research Involving Human Subjects on April 23rd, 2020 (DVG 146). The data is anonymous and in aggregated form, and the need for consent was waived.

Results

There were 107 pregnancy-related deaths between 2015 and 2019, of which 62 were maternal deaths (Figure 1). In this time frame, 50.051 live births were recorded, yielding an MMR in Suriname of 127 per 100.000 live births. The underreporting rate was 24% since the vital registration reported 47 maternal deaths. Figure 2 gives an overview of the MMR reported by vital registration and CEMD from 1990 – 2019. The highest MMR was 226 (CEMD-I), followed by 184 in 2007 and 2018. Underreporting decreased significantly ($p < 0.001$) from 62% in CEMD-I to 26% in CEMD-II and 24% in CEMD-III. Deceased women were significantly more often of advanced age in the first CEMD compared to the latter two CEMD (36%, n=23/64 vs CEMD-II 18%, n=12/65 and CEMD-III 21%, n=13/62) (Table 1). Other significant differences among the three confidential enquiries are the geographic location (rural or urban) where the maternal deaths and concomitant perinatal deaths occurred. While 22% (n=14/64) of women died in the rural interior in CEMD-I, this percentage was 6% (n=4/65) in CEMD-II and 7% (n=4/62) in CEMD-III. The proportion of women with a concomitant perinatal death was significantly lower in CEMD III (33%, n=18/55) than the previous two CEMD (CEMD-I 66%, n=42/64 and CEMD-II 64%, n=36/57).

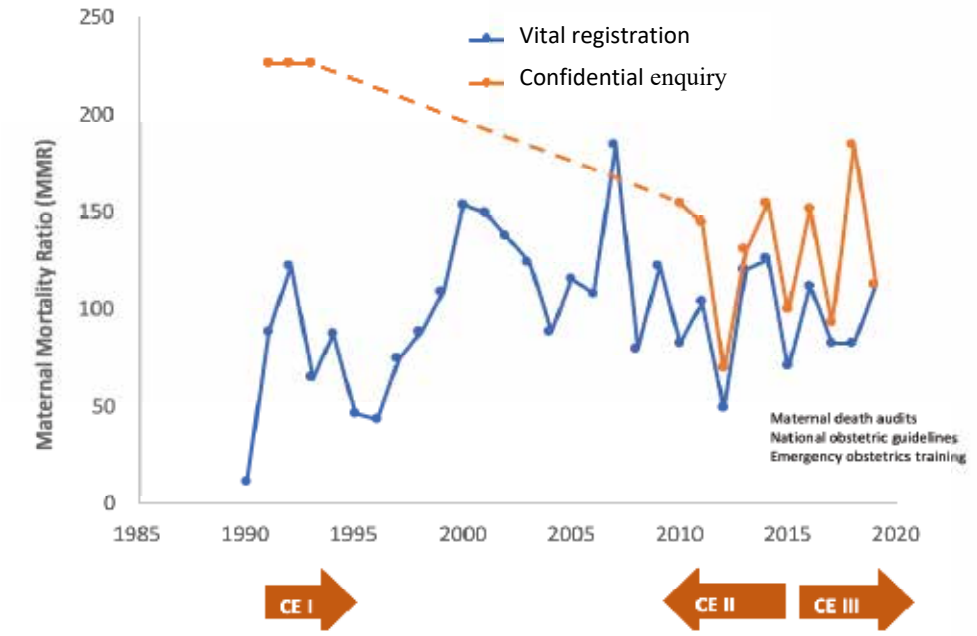
Figure 1. Flowchart of the pregnancy-related deaths in Suriname, 2015-2019



In CEMD-III 18% (n=11/62) of women died at home or during transportation and 23% (n=14/62) were already in poor medical condition (in a coma, or need for resuscitation) upon arrival at a health facility (18%, n=11/62 at a hospital and 5%, n=3/62 at a primary health care centre).

Additionally, in CEMD-III significantly more women were uninsured (25%, n=15/59 vs 0 CEMD-II vs 9%, n=6/64 CEMD-I, ($p < 0.001$)) compared to the previous CEMD. More than two-thirds of the deceased women had social insurance in CEMD-I (72%, n=46/64) and CEMD-II (71%, n=45/65); in CEMD-III social insurance did not exist anymore.

Figure 2. Overview of the maternal mortality ratio (MMR) of the confidential enquiries into maternal deaths (CEMD) in Suriname in relation to vital registration



The prevalence of unspecified deaths increased significantly in time (CEMD-I 2%, n=1/64, CEMD-II 5%, n=3/65, CEMD-III 18%, n=11/62, p=0.002) (Figure 3 and 4). The unspecified deaths of CEMD-III (n=11) occurred at home, primary care clinics or shortly after hospital admittance in nine cases. In two cases multiple co-morbidities (diabetes, sepsis, HIV, severe anaemia) were diagnosed.

In Table 2 the maternal deaths of CEMD-III are categorised in accordance with the WHO ICD-MM groups of underlying causes.[28] The group "All other obstetric causes" included the most frequent underlying causes in CEMD-III (29%, n=18/62), much higher than in the two previous CEMD (CEMD-I 14%, n=9/64 and CEMD-II 17%, n=11/65, p=0.08) (Figure 4).

Table 1. Characteristics of the maternal deaths of the three confidential enquiries into maternal deaths

	1991-1993[1] **CEMD-I** n=64 (%)	**2010-2015[2]** **CEMD-II** n=65 (%)	**2015-2019[3]** **CEMD-III** n=62 (%)	**p-value**
Age				**<0.01**
<20 years	11 (17)	11 (17)	6 (10)	
20-35 years	30 (47)	42 (64)	43 (69)	
>35 years	23 (36)	12 (18)	13 (21)	
Ethnicity			*n=61*	
Maroon	22 (34)	24 (37)	26 (41)	
Creole	14 (22)	13 (20)	14 (22)	
Hindustani	18 (28)	12 (18)	7 (11)	0.46
Javanese	5 (8)	8 (12)	3 (5)	
Mixed	n/a	5 (8)	4 (6)	
Indigenous	5 (8)	3 (5)	5 (8)	
Other	n/a	n/a	2 (3)	
Insurance		*n=63*	*n=59*	
Social	46 (72)	45 (71)	-	-
State	12 (19)	10 (16)	28 (47)	
Private	-	8 (13)	16 (27)	
None	6 (9)	0	15 (25)	
Residency			*n=56*	
Area 1 *Urban, Para'bo-Wanica*	35 (55)	40 (62)	34 (61)	
Area 2 *Urban, Nickerie*	9 (14)	4 (6)	2 (4)	0.19
Area 3 *Rural Coastal, Coronie, Saramacca, Para, Commewijne, Marowijne*	6 (9)	10 (15)	12 (21)	
Area 4 *Rural interior, Brokopondo, Sipaliwini*	14 (22)	11 (17)	8 (14)	
Parity at time of death	*n=63*		*n=57*	
Nullipara	16 (25)	5 (8)	11 (19)	
1-2	19 (30)	31 (50)	20 (35)	0.06
≥ 3	28 (45)	26 (42)	26 (46)	

Table 1. Continued

	1991-1993[1] CEMD-I n=64 (%)	2010-2015[2] CEMD-II n=65 (%)	2015-2019[3] CEMD-III n=62 (%)	p-value
Mode of delivery	*n=46*	*n=41*	*n=47*	
Vaginal Delivery	31 (67)	25 (61)	23 (49)	
Ventuose delivery	2 (4)	3 (7)	3 (6)	0.44
Caesarean Section	13 (28)	13 (32)	21 (45)	
Time of death				
Abortion (<20 weeks)	2 (3)	5 (8)	7 (11)	
Antepartum	16 (25)	15 (23)	8 (13)	0.23
Postpartum	46 (72)	45 (69)	47 (76)	
Location of death				
Hospital	47 (73)	55 (84)	48 (77)	
Primary care clinic	8 (13)	5 (8)	3 (5)	0.26
At home or during transport	9 (14)	5 (8)	11 (18)	
Geographic location of death			*n=56*	
Area 1 *Urban, Para'bo-Wanica*	35 (55)	56 (86)	46 (82)	
Area 2 *Urban, Nickerie*	9 (14)	2 (3)	2 (4)	
Area 3 *Rural Coastal, Coronie, Saramacca, Para, Commewijne, Marowijne*	6 (9)	3 (5)	4 (7)	**<0.01**
Area 4 *Rural interior, Brokopondo, Sipaliwini*	14 (22)	4 (6)	4 (7)	
Perinatal death		*n=57*	*n=55*	
	42 (66)	36 (64)	18 (33)	**<0.01**
Postmortem autopsy	n/a	2 (3)	3 (5)	

Legend

[1]Confidential enquiries into maternal deaths 1991-1993 (CEMD I), adapted (Mungra et al. 1999)**;** [2] Confidential enquiries into maternal deaths 2010-2014 (CEMD II), adapted (Kodan & Verschueren et al. 2017); [3] Confidential enquiries into maternal deaths 2015-2019 (CEMD III)**;** [4] Hospital births 2016-2017 (Verschueren et al. 2020).

There was a significant decrease in obstetric haemorrhage as underlying death cause over time (CEMD-I 30%, n=19/64 vs CEMD-II 20%, n=13/65 vs CEMD-III 11%, n=7/62, p=0.04). The prevalence and underlying cause of maternal deaths before 20 weeks changed: in CEMD-I all cases were caused by ectopic pregnancies (3%, n=2/64), in CEMD-II death was due to haemorrhage from an ectopic pregnancy and sepsis following an induced abortion (3%, n=2/65), and in CEMD-III death was from haemorrhage caused by an ectopic pregnancy and three induced abortions (6%, n=4/62). While there were no cases of maternal suicide reported in CEMD-I, there was one case (2%, n=1/65) in CEMD-II and five cases in CEMD-III (8%, n=5/62) (Figure 4). The most recent confidential enquiry (CEMD-III) reported more late maternal related deaths (n=12) compared to the CEMD-I (n=3) and CEMD-II (n=8). In 67% (n=8/12) of the late maternal deaths between 2015 and 2019, complications started already during pregnancy or within 42 days after delivery. Of these 75% (n=6/8) were due to complications of postpartum cardiomyopathy (Supplementary Table 1).

Figure 3. Classification of maternal deaths in Suriname in type of maternal death (direct, indirect, unspecified)

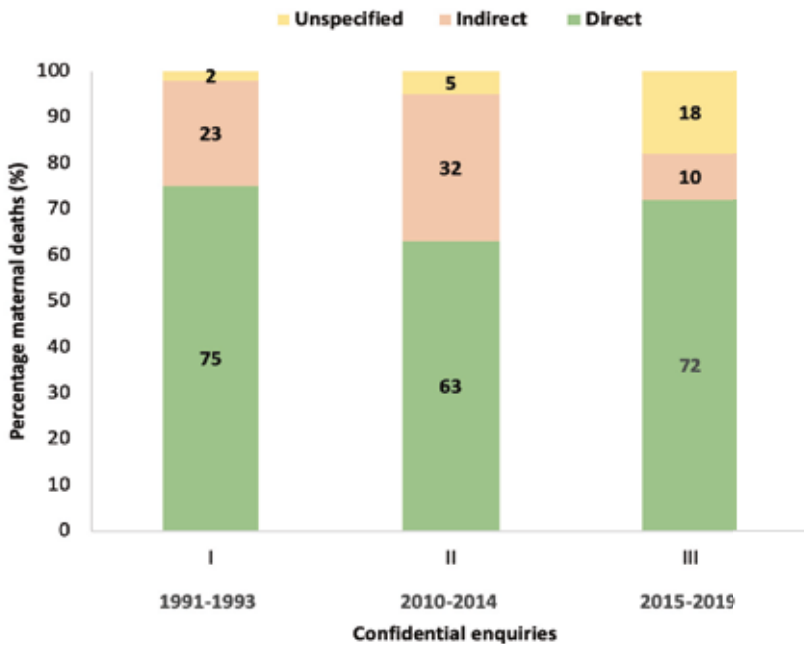
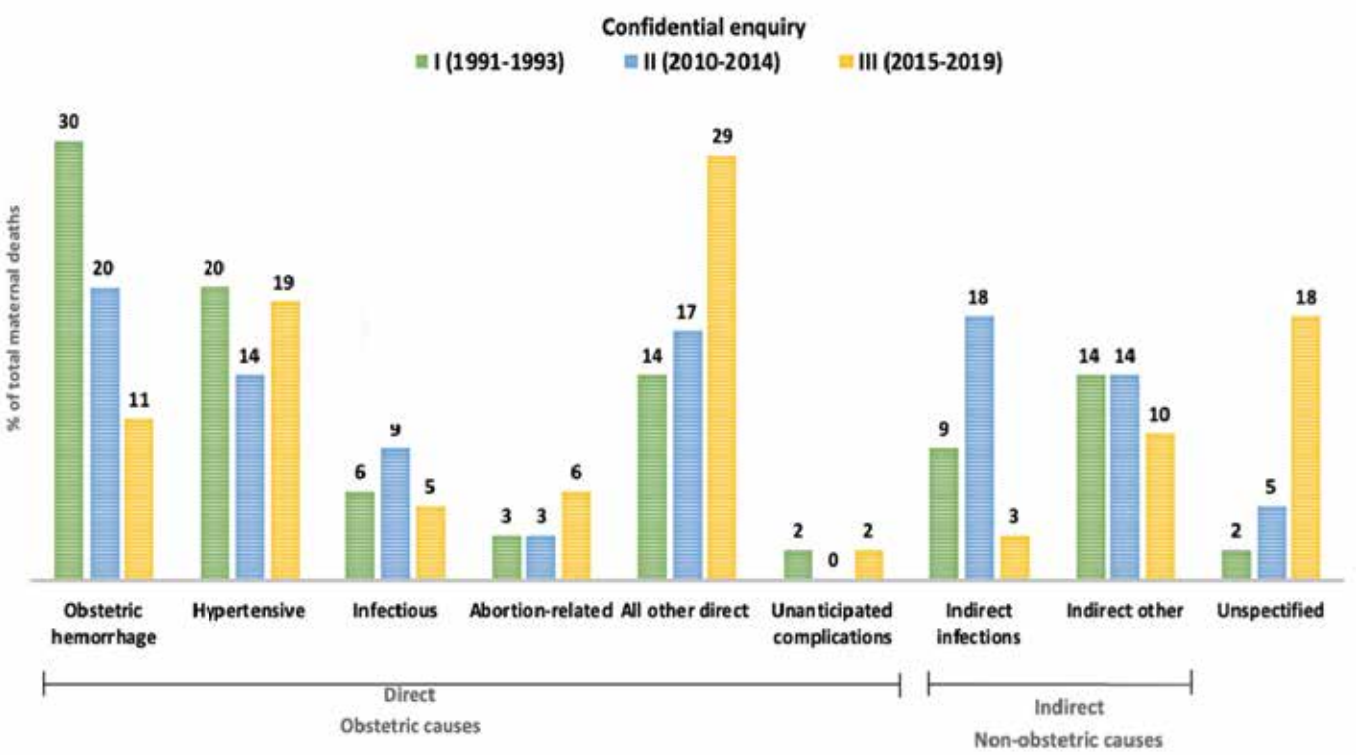


Figure 4. The underlying causes of maternal deaths according to WHO ICD-MM[1]



Reference: [1] World Health Organization. ICD-10 to deaths during pregnancy, childbirth and the puerperium: ICD-MM. 129, 30–33 (2015)

Table 2. Groups of underlying causes of maternal deaths in Suriname from 2015-2019 conform to the WHO ICD-MM [1]

	Type	Group number/name	Case description/numbers
1	Maternal death: Direct	Pregnancies with abortive outcomes (n=4)	Abortion with haemorrhagic shock (n=3); ectopic pregnancy (n=1)
2	Maternal death: Direct	Hypertensive disorders (n=12)	Eclampsia (n=6); intracerebral haemorrhage (n=4); HELLP [2] (n=3)
3	Maternal death: Direct	Obstetric haemorrhage (n=7)	Postpartum (n=6); placental abruption (n=1); died during transportation to a hospital (n=2); hysterectomy performed (n=3)
4	Maternal death: Direct	Pregnancy related infections (n=3)	Post caesarean section (n=2)
5	Maternal death: Direct	Other obstetric complications (n=18)	Suicide (n=5); amniotic fluid embolism (n=6); postpartum cardiomyopathy (n=2); thrombo-embolism (n=5)
6	Maternal death: Direct	Unanticipated complications of pregnancy (n=1)	Anaesthesia complication
7	Maternal death: Indirect	Non-obstetric complications (n=6)	Sickle cell anaemia (n=4) [sepsis (n=2) postpartum haemorrhage and ischemia (n=1), encephalopathy (n=1)]; HIV/Aids cardiomyopathy (n=1); heart failure/ventricular septum defect (n=1)
8	Maternal death: Direct	Unspecified (n=11)	Died at home or shortly after hospital admittance (n=9). Complex cases, cause of death undetermined (n=2)
9	Pregnancy related (<42 days postpartum)	Coincidental causes (n=7)	Malignant tumors n=3 [lymphomas and HIV/AIDS (n=2), ovarian carcinoma (n=1)]; AIDS related cryptococcus meningitis in early pregnancy (n=1); car accident (n=1); drowning (n=2)

Legend

[1] World Health Organization. ICD-10 to deaths during pregnancy, childbirth and the puerperium: ICD-MM. 129, 30–33 (2015); [2] HELLP: hemolysis, Elevated Liver enzymes, and Low Platelets.

In Table 3, an overview is provided of the substandard care analysis by the review committee conform the three delays model. In all three CEMD, the maternal mortality committee agreed that substandard care existed in at least 87% of the maternal deaths.
In addition, 47% of the deaths were preventable in both CEMD-II (n=28/65) and CEMD-III (n=29/62). Patient delay did not differ significantly [38% (n=36/62), 29% (n=17/59), (38 n=23/61)] in CEMD-I, II, III, respectively. Phase III delay, however, predominated in all three CEMD [CEMD-I 65% (n=41/62) vs CEMD-II 80% (n=47/59) vs CEMD-III 77% (n=47/61)].

Table 3. Substandard care analysis of the maternal deaths in Suriname in the three confidential enquiries of Suriname

	1991-1993 **CEMD-I** [1] n=62	**2010-2014** **CEMD-II** [2] n=59	**2015-2019** **CEMD-III** [3] n=61
First delay	36 (38)	17 (29)	23 (38)
Second delay	N/A	9 (15)	5 (8)
Third delay	41 (65)	47 (80)	47 (77)
Preventable maternal death (according to MDR[4] committee)	N/A	28 (47)	29 (47)
Problems with organization of care (logistics, availability of medication, blood, ICU bed)	24 (39)	N/A	18 (29)
Existence of any form of substandard care	59 (95)	56 (95)	54 (87)

Legend
[1] Confidential enquiry into maternal deaths (CEMD I), adapted (Mungra et al. 1999); [2] Confidential enquiries into maternal deaths (CEMD II), adapted (Kodan & Verschueren et al. 2017); [3] Confidential enquiries into maternal deaths 2015-2019 (CE III); [4] Maternal Death Review; N/A: not applicable

DISCUSSION

Three CEMD in Suriname showed an overall declining trend in the MMR, with a reduction of 44% in 28 years. In all three CEMD, deceased women were more often of African descent, died postpartum and in hospitals. In the two most recent CEMD there were significantly 1) fewer deceased women of advanced maternal age, 2) fewer deaths in the rural interior, and 3) fewer concomitant perinatal deaths compared to CEMD-I. In 41% of the maternal deaths of CEMD-III, the location of death was at home, the primary health clinic or soon after reaching a health facility. Also, in CEMD-III, the percentage of uninsured women was the highest among the maternal deaths in the three CEMD. More than two-thirds of deceased women had social insurance in CEMD-I and II, which reflected their low socioeconomic class.

Prevalence of maternal deaths in pregnancies with abortive outcomes, from "other obstetric causes" (especially maternal suicide), unspecified deaths, and late maternal deaths increased over time. In two-thirds of the late maternal deaths in CEMD-III, the onset of the complications resulting in death started earlier in pregnancy and puerperium. Substandard care analysis showed similar trends over the years, with predominantly a Phase III delay and no significant difference in phase one delay.

High rates of maternal mortality is a marker of inequitable and unequal health care.[8] MMR in low-income countries can be 60 times higher than in high-income countries and relates to socioeconomic determinants and health system arrangements.[3,36-38] The Sustainable Development Goals (SDG) target 3.1 aimed to reduce the MMR in any country by two-thirds with 2010 as a baseline.[8] To reach this target, Suriname needs to progress to an MMR of below 51 in 2030 (the MMR in 2010 was 154/100.000 livebirths). Unfortunately, the average MMR was almost the same in the recent 10 years. This trend questions if the SDG target will be reached in 2030. In addition, the influence of the economic crisis and the Covid-19 pandemic on the access and availability of care and subsequently on maternal mortality in Suriname has yet to be determined.

Over the years, women of African origin were more prone to maternal mortality compared to women of non-African descent in Suriname. Racial and ethnic

differences in maternal mortality have been reported extensively by many countries.[3,39-42] The etiology of ethnic disparity is multifactorial and involves disparities in health outcomes (determined by biology, genetics, health behavior), health care access (determined by insurance, socioeconomic status, education level) and quality of medical care.[40,43] In a recent study on ethnic disparities and childbirth in Suriname, we reported higher risks for women of African descent on adverse obstetric outcomes such as stillbirth, preterm birth, and low Apgar scores.[22] Tailor-made programs focused on this ethnic group are needed to prevent and treat these adverse obstetric outcomes.

Women still died because of ectopic pregnancies in CEMD-III and the number of women dying from (self)induced abortions even increased in Suriname. In Latin American and the Caribbean (LAC) and Sub Saharan Africa (SSA) regions, maternal deaths from pregnancies with abortive outcomes were the highest globally (10%) and only slightly higher than the prevalence in Suriname in CEMD-III (8%).[4] Induced abortions are illegal in Suriname, though tolerated and often performed by skilled health care providers.[15] Also, this issue is shrouded in strict social taboo due to its illegal character, making it difficult to tackle and possibly leading to underreporting of abortion-related deaths.

Deaths from “all other obstetric causes” were the most frequent underlying death cause in CEMD-III and included deaths due to amniotic fluid embolism, thromboembolism or suicide. In CEMD-III there were five cases (8%) of maternal death from suicide and none in CEMD-I. Prevalence of maternal suicide varied from 1% in Africa to 3% in the America's and the Mediterranean region.[44,45] The WHO ICD-MM, published in 2012, classified antepartum and postpartum suicide as a direct maternal death under the group "all other obstetric causes", which resulted in increased reporting.[28,46] However, the increase in pregnancy-related suicide was not only from increased reporting. Perinatal (antepartum and postnatal) depression is a major risk factor for suicide and highly prevalent in LMIC.[45] The WHO developed a mental health action plan in 2012 to highlight the importance of mental health in achieving health for all people and puts the focus on prevention strategies.[47] In Suriname, 25% of all women suffer from depression and anxiety

disorders, and the number of suicide cases has increased steadily over the years.[21,48] Fear for stigmatization and discrimination could prevent those in need seeking help.

The prevalence of unspecified maternal deaths increased over the years in Suriname. Underlying cause attribution is difficult, either because of the complexity of the case or the deplorable medical conditions, which left no time for additional diagnostic investigations. In complex cases, involving several co-morbidities or the co-occurrence of direct and indirect conditions, determination of the initiating event leading eventually to death is challenging.[49] In both situations, post-mortem autopsy is the gold standard to clarify most of the uncertain causes. However, it is seldom performed in Suriname due to financial and cultural reasons.[50,51] The prevalence of late maternal deaths was the highest in CEMD-III. In two-thirds of these cases, the initiating event developed during pregnancy or puerperium, but ultimately the death occurred later than 42 days postpartum. Improved and more specialised health systems in Suriname prolonged the survival of woman experiencing complications in puerperium.[3,21,32,52] Most of these deaths were caused by postpartum cardiomyopathy. The relative contribution of cardiac diseases becomes more relevant as MMR lowers and countries undergo "obstetric transition" from more direct causes to indirect causes and towards more non-communicable diseases.[53] As a result of the classification as late maternal death, these cases were often neither counted in the MMR nor reviewed, missing opportunities to evaluate the "lesson learned".

Substandard care analysis of the maternal deaths in all three studies showed that delay in care occurred predominantly in the hospitals (phase III delay) and that almost half of the deaths were preventable, according to the evaluation of the MDR committee. Delay in seeking care (Phase I delay) accounted for an estimated one-third of the maternal deaths in all three studies. Although the health care infrastructure in Suriname improved nationwide and the National Basic Health Insurance Law was passed in 2014, Phase I delay was not significantly different over the years.[21,54] This law was intended to achieve universal health coverage and

provide equitable health care to everyone.[54] However, several gaps in this system and concomitant deteriorating financial position of the country since 2015 left people, who were financially dependent on the government for their insurance, uninsured and delayed their decision to seek health care and their access to care.[21,26] This delay could probably also explain the increase in unspecified death and death upon arrival at a facility in the most recent CEMD.

Recommendations to reduce preventable maternal deaths in Suriname

1) Similarities among the CEMD include that most maternal deaths occurred in hospitals, postpartum and in women of African descent. We, therefore, advise improving the continuum of care aimed to prevent maternal deaths.[55,56] This includes the quality of clinical care, outpatient antenatal and postnatal care and family/community care.[8,55,56] The quality of care is currently being addressed by the national guidelines development on obstetric emergencies and systematic national maternal death reviews (MDR).[14,17] It is essential that these guidelines will be revised and implemented and that actions follow on the recommendations from the MDR to achieve improvements in care[14]. For improvement of outpatient antenatal and postnatal care, referral pathways should be revised, and practical national guidelines developed. Development of tailor-made (prevention) programs (e.g. contra conception, anaemia prevention, antenatal care coverage) should focus on the vulnerable groups. Family/community care needs to address the persisting inequity among different social classes and ethnicities. These interventions include improving educational opportunities, employment, housing and nutrition.

2) To attribute underlying causes of maternal deaths reliably, we strongly recommend post-mortem autopsy in deaths of unknown cause in (recent) pregnant women.

3) Delay in seeking care (phase I) delay did not decrease over the years, which emphasises the need to improve accessibility and implement universal health coverage.[57,58] We request policymakers to assess the gaps and practicability of the

basic National Basic Health Insurance Law and how to ensure universal access to health care without suffering financial hardships.

4) The cases of deaths from antenatal suicide in CEMD-III accentuates the need to raise awareness and offer psycho-social support for mental health disorders such as depression during pregnancy and postpartum.[45,59]

5) We encourage discussion regarding the legalization of abortion since abortion-related maternal deaths are still occurring in Suriname. Contra conception use should be accessible, affordable and be promoted to prevent unplanned and unwanted pregnancies.

6) Late maternal deaths (>42 days postpartum) often result from diseases during pregnancy or within 42 days postpartum and it is, therefore, crucial to also review and report these. Valuable lessons can be learned, which can lead to a response and maternal death reduction[32,52]. We agree with the proposition by the ICD-MM workgroup to incorporate these late deaths under a new group "comprehensive maternal death" in the ICD-11.[3] Postpartum cardiomyopathy was the underlying cause of most of the late maternal deaths and highlights the need for awareness, prevention, early diagnosis of cardiac diseases in pregnancy and puerperium and close collaboration among cardiologists and obstetricians.

7) The strong focus on the COVID-19 pandemic has led to reduced attention for maternal health care and a subsequent decrease in the access and quality of care worldwide.[60] We need to be aware of the potential collateral damage in maternal and perinatal care COVID-19 is causing and look for alternative ways to continue the quality of care improvements and the systematic review of maternal deaths.

Strengths and limitations

This study compared three CEMD, and the timing of the first two coincides with the MDG start and endpoint. Various extensive methods were used to identify pregnancy-related deaths and could analyze gaps and issues to be addressed in-depth. Since systematic maternal death reviews are not yet implemented in many countries globally, it is praiseworthy that it was possible in Suriname and supported by several stakeholders.[61] Policymakers can use this study for advocacy

to prioritise maternal health care on the agenda of decision makers. Because of the small population in Suriname, the absolute number of maternal deaths was low, and this is one of this study's limitations. Not all required information could be collected. For example, in two hospitals there was no comprehensive digital database for deceased persons; therefore, the RAMoS could not be completed. Additionally, the Bureau of Public Health did not provide information from the death certificates, resulting in unavailability of the cause of death information regarding deceased women of reproductive age. Therefore, data cross-check was not possible. However, we were able to capture a vast amount of data about pregnancy-related deaths for the CEMD, sufficient to substantially contribute to important recommendations to reduce preventable maternal deaths in Suriname.

CONCLUSION

Audit and review of all maternal deaths were prospectively implemented in Suriname in 2015. Based on the data collected in three CEMD, MMR in Suriname almost halved in 28 years; however, this progress is insufficient to achieve the SDG target in 2030. Socioeconomic determinants influence maternal death reduction in Suriname. Quality-of-care improvement, better accessible and equitable health care for specific groups, enhanced mental and abortion-related health care, and early detection/therapy of cardiac diseases are key elements to eliminate preventable maternal deaths.

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Supplementary Table 1. Causes of late maternal deaths and coincidental late pregnancy-related deaths between 2015-2019 in Suriname.

Underlying cause of death	Onset of symptoms	Timing of death postpartum	Special remarks
Late maternal deaths (n=12)			
Postpartum cardiomyopathy (n=7)	Within six weeks postpartum (n=6)	54-150 days	Developed cardiomyopathy following previous pregnancy, died 275 days postpartum (n=1)
Pre-existent hypertensive disorders and cerebral bleeding (n=3)	Unknown	57, 78 and 240 days	
Necrotic myoma in pregnancy, developed pulmonary embolism (n=1)	During pregnancy	60 days	
Placental abruption (n=1)	During pregnancy	120 days	
Coincidental late pregnancy-related deaths (n=4)			
Liver cirrhosis with ascites, severe anaemia/thrombopenia (n=1); malignancies (n=3) (colon carcinoma, pancreatic carcinoma and liver carcinoma)	During pregnancy or within six weeks postpartum	46-108 days	

General discussion

9

"Women are not dying from disease we cannot treat. They are dying because societies have yet to make the decision that their lives are worth saving"

Professor M.F. Fathalla

Suriname's steps in the implementation of the Maternal Death Surveillance and Response (MDSR)

Implementing maternal death surveillance and response (MDSR) in Suriname

Implementing maternal death surveillance and response (MDSR) is seen as a key step toward the reduction of maternal deaths.[1-3] We have completed the MDSR cycle in Suriname based on the findings of the initial studies of this thesis. Ten years of maternal mortality in Suriname were analyzed, which was possible because of health care providers' commitment, accountability and ownership.[2-3] The most fundamental intervention in this implementation process was the installation of a national maternal death review (MaMS, Dutch acronym) committee in Suriname, responsible for the review of every maternal death. Since this installation in 2015, for the first-time maternal deaths were systematically reviewed in Suriname.

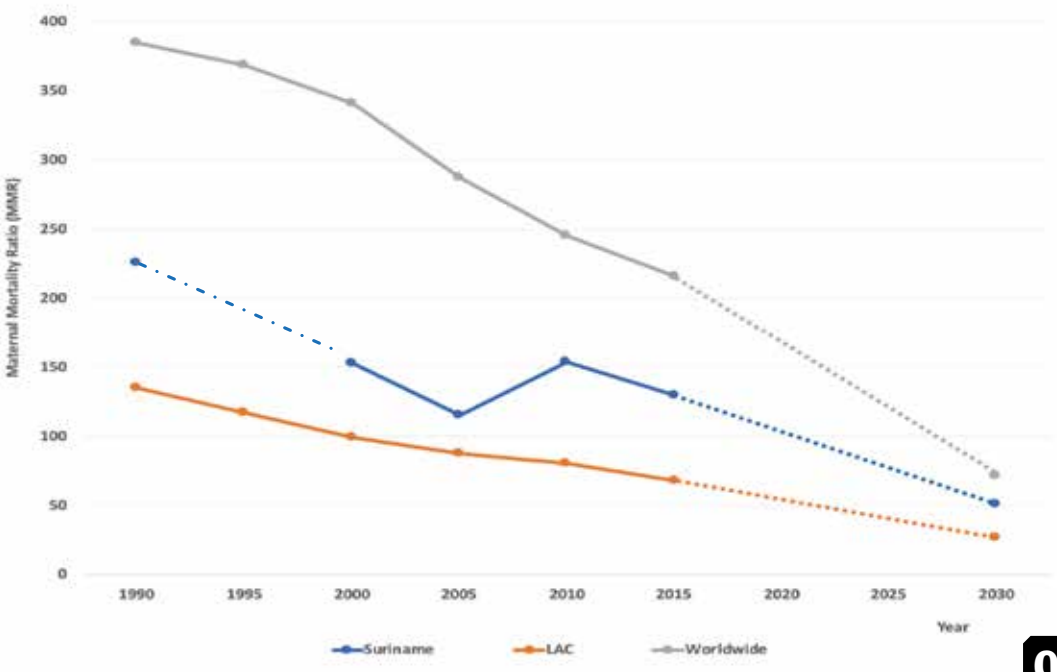
Maternal mortality ratio in context

In Figure 1, the MMR globally, of Suriname, and the Latin American Caribbean (LAC) region are illustrated, starting from 1990 toward the expected national SDG target of 2030.[4] The average Maternal Mortality Ratio (MMR) stayed almost the same in Suriname in the ten year's study period (MMR of 130 in 2010-2014 and 127 in 2015-2019). When compared to 1990, maternal deaths declined with 44% in 2015, which was in line with the global MMR decline. However, according to the WHO Millennium Development Goal (MDG) of 75% decline of MMR in 2015, this progress was insufficient.[5,6] The SDG has set the target of a national MMR reduction of at least two thirds in 2030 as compared to the 2010 MMR. For Suriname, the expected target in 2030 should be an MMR of 51 or less.

The effect of the interventions in this thesis are not reflected in a decline in MMR in the last ten years. However, a framework of MDSR has been set up, that provides information which could enable all stakeholders in Suriname to collaborate in order to reach the SDG target of 2030. Due to the rich information provided by the implementation of the MDSR we were able to show a change in the causes and

characteristics of maternal deaths which are not reflected by a mortality ratio alone. The specific findings of the individual studies and recommendations for future research are discussed here.

Figure 1. Maternal Mortality Ratio (MMR) in time toward SDG target in 2030 worldwide, the Latin American Caribbean (LAC) and Suriname



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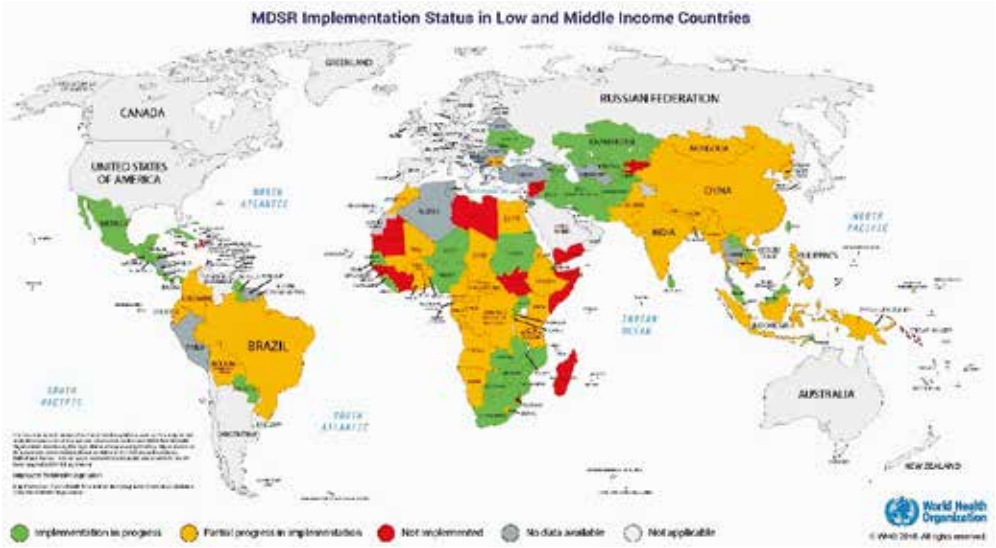
MDSR implementation status of Suriname

The extent to which countries implemented MDSR was measured by the WHO in 2015 in 67 countries, using key MDSR policy and principles as indicators.[3,7] Figure 2 depicts the MDSR implementation status in low- and middle-income countries in 2015 and indicates that no data was available for Suriname. Several countries

showed varying degrees of MDSR implementation.[7] The first national maternal mortality review (MaMS, Dutch acronym) committee was established in Suriname in 2015, in response to the recommendations of the 2010 - 2014 study (this thesis). In Table 1, an overview of the implementation status of MDSR in Suriname before and after the start of this thesis in 2015 is provided by the evaluation of the twelve key components of MDSR, as defined by the WHO MDSR working group. Only one key component (the facility-based audits) was partially implemented before 2015 in Suriname.[3,7] Following the recommendations gleaned from the research in this thesis, five more components were (partially) implemented (Table 1).

Figure 2. MDSR implementation in low- and middle-income countries in 2015



Reference: World Health Organization. Time to Respond, a report on the global implementation of Maternal Death Surveillance and Response. 2016

Table 1. Evaluation of the key components of a National Maternal Death Surveillance and Response System in Suriname until 2015 and from 2015 – 2020

	Until 2015	2015 - 2020
Key policy indicators		
National policy for notification of maternal deaths	no	no
National policy to review maternal deaths	no	yes
A national maternal death review (MDR) committee in place	no	yes
Subnational MDR committee in place (facility-based audit)	incidental	incidental
Both national and subnational MDR committee in place	no	no
At least biannual meeting of national MDR committee	N/A	yes
Key principles to guide system operation		
Notification and investigation of all suspected maternal deaths in women of reproductive age	no	incomplete
Notification within 24 hours of maternal deaths in facilities or 48 hours for community deaths	no	no
Zero reporting when no suspected maternal deaths have occurred	no	no
Timely review and analysis at local and national level	no	sometimes
Timely publication of findings	no	no
Continuous monitoring of the MDSR system and implementation of recommendations	no	no

References:
1. World Health Organization. Time to Respond, a report on the global implementation of Maternal Death Surveillance and Response. 2016.
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Identification and notification of maternal deaths

Tracking every maternal death is one of the key elements of the MDSR.[8] In general, maternal deaths remain unrecorded and underreported because of malfunctioning vital registration systems.[1,9,10] Underreporting rates of 20% in Jamaica, 43% in Malawi, and 58% in Morocco have been published.[9-11] Improving the surveillance system by adding active hospital surveillance in obstetric wards to vital registration in Suriname seemed to be insufficient.[12,13] A method applied in our studies to identify more maternal deaths is the screening of deceased women of reproductive age for a (recent) pregnancy: the reproductive age mortality survey (RAMoS). The RAMoS was performed by several medical students. The underreporting rate through misidentification was 25% between 2010 and 2019, which was lower than the 63% underreporting mentioned in the 1991 - 1993 study.[12,14,15] Besides incomplete reporting due to misidentification, 65% underreporting in Suriname during 2010 and 2014 came from misclassification.[12] High rates of underreporting because of misclassification were also described in studies from Jamaica (76%) and Morocco (42%).[9,11] Misclassification can be prevented by multidisciplinary case review, accurate underlying cause attribution and correct coding of death.[9,16]

Maternal death review

Maternal death review (MDR) is central to the MDSR cycle. During the 2010-2019 period, 149 pregnancy-related deaths were reviewed in Suriname, of which 127 were maternal deaths. Following the identification of maternal deaths, information-gathering procedures were initiated by medical students. Case summaries were composed extracting information from the medical file, verbal autopsy, and postmortem investigation reports if available.[1,17] Subsequently, an MDR was conducted, which provides insight into the causes and circumstances of the death.[18] The reviews were possible because of the confidential approach used. The "no blame, no shame" principle and the ascertainment of no litigation or disciplinary measures were of paramount importance during the reviews and increased facility and health care providers' accountability and involvement.[3,17]

Attribution of underlying causes in pregnancy-related deaths may be complicated, when a death was preceded by a chain of events.[19] A comparison of the classification of similar pregnancy-related cases (of the 2010 - 2014 study) by committees of different countries showed varied underlying cause attribution and classification. In 15% (n=11/73) of the cases opinions differed even in whether a death was considered to be a maternal death or not. Postmortem autopsies, the gold standard in underlying cause determination, were performed in only 4% (n=5/127) of the maternal deaths during the last ten years in Suriname. This is in line with the global figure, where pathology evaluation is seldom performed in maternal deaths.[19] Particularly in low resource countries, where the need is highest, postmortem investigations were reported to be poorly accepted and challenging due to cultural beliefs, logistics and financial problems, especially in rural areas.[20,21]

Analysis and recommendations

Maternal death audits resulted in the attribution of consensus-based underlying causes and substandard care analyses. Compared to Suriname (2015 - 2019), Latin American Caribbean (LAC) countries reported a higher prevalence of obstetric haemorrhage (23% vs 11%), hypertensive disorders (22% vs 19%) and of direct obstetric sepsis (8% vs 5%).[22] Maternal death audits in Suriname showed a declining trend over three decades in sepsis and obstetric haemorrhage as underlying causes of death. However, hypertensive disorders, unspecified maternal deaths, all other obstetric (as antenatal suicide) and late maternal deaths increased over the years. Care provided in the hospitals in Suriname was considered substandard by the review committees, mainly due to issues concerning the quality of health care (third delay), as in most Latin American countries.[1] The in-depth studies (sepsis, postpartum haemorrhage (PPH)) identified specific gaps in care that need to be addressed to avoid preventable maternal deaths.

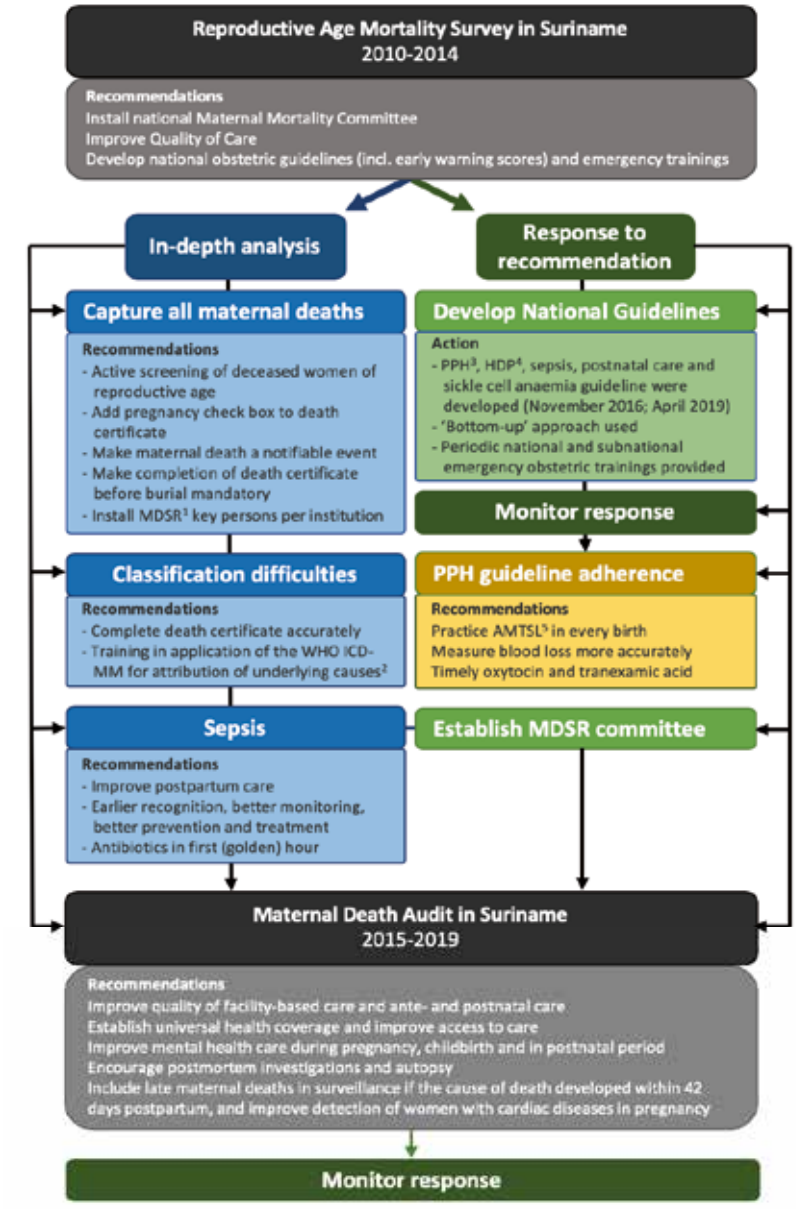
Respond to recommendations and monitoring of response

In a case study in several low-income countries successful MDSR implementation was related to the process of ownership taken by professional organizations (gynaecologists, midwives, general practitioners).[2] Therefore, during our research we succeeded in involving the college of obstetricians/gynaecologists, the organization of midwives, the Ministry of Health (MOH)/Bureau of Public Health (BOG) and the Pan American Health Organization (PAHO) to ensure responses to the recommendations from these studies. The first response was the establishment of a maternal mortality review committee (MaMS) to review maternal deaths structurally. The second response (in 2016 and 2019) was the development of national guidelines with concomitant obstetric emergency training. The PPH national guideline use was monitored by conducting a criteria-based audit in 2017. The audit concluded that the guidelines were not yet fully implemented and the use of and adherence to the guidelines were inadequate. However, the study was conducted only several months after the guidelines were introduced, which could explain the limited use. Thus far, there is no structured program in place in Suriname to monitor responses. Nevertheless, increased awareness and improved quality of care probably resulted in a lower prevalence of maternal deaths from obstetric haemorrhage during 2015 - 2019 (11%), as compared to the findings in previous studies (30% [1991 - 1993] and 20% [2010 - 2104]). The key findings of maternal mortality research of this thesis were summarised in Table 2. Figure 3 gives a summary of the MDSR implementation in Suriname, and the recommendations from the analysis of ten years of maternal mortality in Suriname, assessing the specific objectives of this thesis.

Table 2. Key findings and achievements of this thesis

Key findings
1. More women (41%) died either at home, in the primary health clinic or soon after arrival in the hospital in the 2015-2019 study than in the 2010-2014 study (16%).
2. Most maternal deaths were in women of African descent, of low socioeconomic class, who died in hospitals and postpartum.
3. Although the average MMR stayed almost the same in ten years, the causes and characteristics of maternal deaths changed significantly.
4. Underlying causes of maternal death between 2010 and 2014 were predominantly direct and included obstetric haemorrhage, hypertensive diseases and sepsis.
5. In the 2015-2019 study, the most frequent causes were "all other obstetric causes" (suicide, amniotic fluid embolism, thromboembolism), hypertensive diseases and unspecified deaths.
6. Underlying cause attribution and classification differ in Suriname and among countries when applying the WHO ICD-MM.
7. Almost half of the maternal deaths were preventable and delay in quality care in the hospitals was the most frequent substandard care factor.
8. Monitoring was inadequate, and no antibiotic treatment was initiated within the gold hour in critically ill septic (recently) pregnant women who died in 2010-2014.
9. Prevention and treatment of postpartum haemorrhage with oxytocin and tranexamic acid was inadequate and not according to the guidelines.
Key achievements
1. All maternal deaths since 2010 were reviewed multidisciplinary.
2. Conducting a Reproductive Age Mortality Survey increased the awareness and involvement of healthcare workers and improved the identification of maternal deaths.
3. A national maternal death review committee was established, responsible for the review and classification of every maternal death.
4. National guidelines on the essential causes of maternal deaths were developed "bottom-up" and combined with obstetric emergency training to improve quality of care.

Figure 3. Summary of Maternal Death Surveillance and Response implementation in Suriname as described in this thesis



Legend [1] MDSR: Maternal Death Surveillance and Response; [2] WHO ICD-MM: International Classifications of Diseases – Maternal Mortality; [3] PPH: postpartum Haemorrhage; [4] HDP: hypertensive disorders of pregnancy; [5] AMTSL: Active Management of Third Stage of Labour

Trend analysis, obstetric transition and socioeconomic influences

Similar trends were seen in the studies analysing maternal deaths in Suriname over almost three decades: the majority of deceased women were of Maroon and Creole ethnicity, died postpartum and in hospitals with substandard care (as concluded by the review committees) in at least 87% of these deaths. The obstetric transition principle describes the transformation of countries over time toward more equitable health systems and lower MMRs.[23] Suriname was in the same obstetric transition stage (stage III) from 1991 to 2019, which concurs with the obstetric stage of most countries in the world.[4] This stage is considered the tipping point where countries transform from direct to more indirect causes of maternal mortality, with direct causes still dominating as reported by the studies in our thesis. Deaths from obstetric haemorrhage decreased, but abortion-related deaths, deaths from hypertensive disorders, unspecified deaths, and deaths from other obstetric causes such as suicide increased over the years in Suriname.

Delay in care was dominated by insufficient care in the health facilities (phase III delay) as decided by the review committees, which is one of the characteristics of obstetric transition stage III. Perinatal deaths concomitant with the maternal deaths decreased significantly over time with improved perinatal care in Suriname.[24] Urbanization and better transportation might have contributed to a significant decreasing trend in maternal deaths in the rural interior of Suriname.[25] Phase I delay has not improved yet indicating that universal access to care is still an issue in Suriname. The passing of the National Basic Health Insurance Law in 2014 was intended to achieve universal health coverage and make equitable health care available to everyone.[26,27] However, several gaps in this system and the deteriorating financial position of the country since 2015 have left those, who were financially dependent on the government for their insurance, uninsured, probably delaying their decision to seek health care.

Thesis Conclusions

This thesis showed that although the average MMR did not decline in the recent ten years, MDSR was implemented and improved. Health care professionals' ownership and involvement were essential in the process of completing the MDSR cycle. Our research on maternal deaths looked "beyond the numbers" and has identified specific issues in the quality of health care in Suriname. We provided recommendations for action and quality improvement at several levels of the health system. Two important recommendations acted on were the installation of a national MDR committee, that systematically reviewed maternal deaths and the bottom-up development of national guidelines on the most important causes of maternal deaths. However, strong government commitment and socioeconomic factors influence the sustainability of the MDSR implementation. Lessons learned from the research in this thesis could be used by other low-and middle-income countries that lack an existing structure for MDSR.

Future implications

Maternal mortality beyond 2020 - the continuum of care

The Sustainable Development Goal (SDG) 3 target 3.1 aims to eliminate preventable maternal deaths, which is part of the bigger goal to ensure healthy lives and promote well-being for all at all ages.[4] This bigger goal puts maternal deaths under the umbrella of maternal health in general, with the focus on the availability of quality preventive health care. The 2018 Declaration of Astana reaffirmed the commitment of the 1978 Declaration of Alma-Ata to prioritise primary health care and universal health coverage, including several aspects of maternal health, such as family planning, healthy pregnancy, and safe childbirth.[28] In this context, the continuum of care principle is a life course approach, which denotes the continuation of care throughout the life cycle, including adolescence, pregnancy, childbirth, postnatal period, and childhood.[29,30] Thus, while the implementation of the MDSR cycle is a priority, Suriname should simultaneously embed this within a continuum of care.[30] The continuum of care connects care during the lifecycle and at places of caregiving (facilities), as shown in Figure 4.[30]

There are different approaches in the places of caregiving in the continuum, which are 1) clinical care in individual facilities 2) outpatient and outreach services such as routine antenatal care or postnatal care, and 3) family and community care, including healthy behavior, women's empowerment, and education. This thesis focused on maternal deaths and the care in facilities (first approach) and identified gaps that have not yet been addressed. These gaps were discussed in the thesis and recommendations provided (Figure 3). In the future, the second and third approach should also be evaluated regarding issues on maternal health that are inextricably linked to maternal mortality reduction. Solely concentrating on facility-based and emergency care is not effective enough and could result in unnecessary and expensive interventions and overmedicalization.[31,32]

Empowerment of healthcare providers

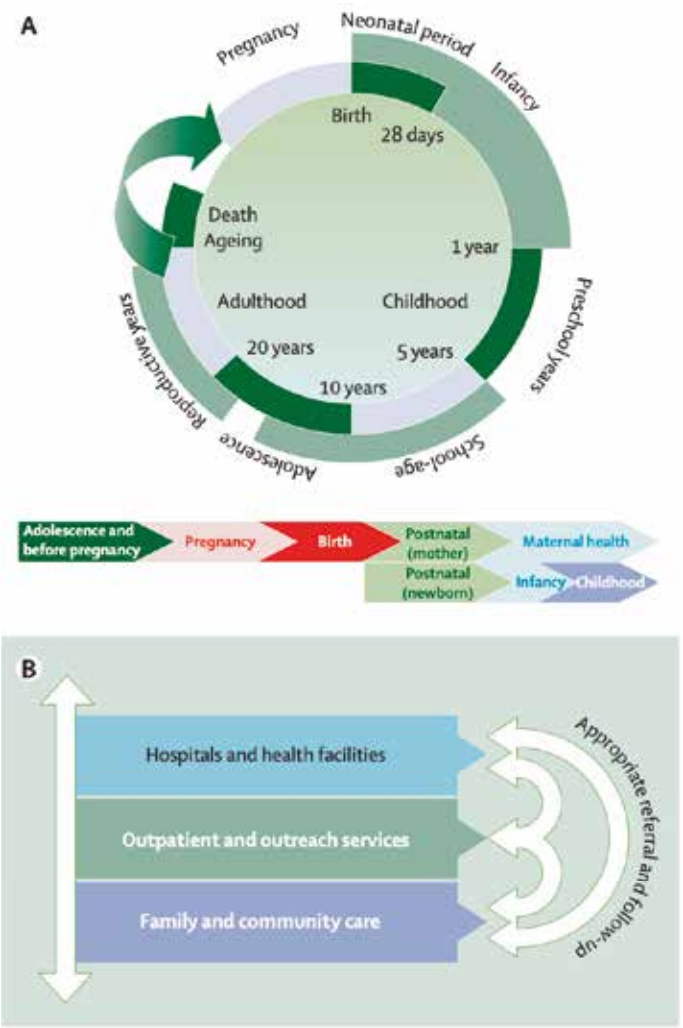
The midwives are the driving forces across this continuum of care principle for maternal health. In midwifery, the scope is extended toward a holistic approach, including respectful maternity care.[31,32] Not surprisingly 2020, has been designated the International Year of the Nurse and the Midwife by the World Health Assembly.[33] Also, in Suriname, strengthening the position of the midwives is essential to achieve universal health coverage and improve maternal health. This includes adequate training of midwives, enabling them to work, integrating their work with other health professionals, and, finally, respecting and valuing them (also financially).[33] The dedication and willingness of involved healthcare providers and policymakers is vital.

Implications for further research

With approximately 10.000 live births every year in a country with an estimated 500,000 inhabitants and MMRs varying between 100 - 150, the absolute number of maternal deaths is low, ten to fifteen deaths annually. Recommendations to improve the quality of obstetric care drawn from individual cases cannot be generalised easily, leading to a strong need for long-term data on maternal mortality, maternal morbidity, near-miss and perinatal mortality/stillbirths. In

addition, implementation is another necessary field of research to monitor and enhance the response to the recommendations. The concept of improving maternal health to reduce maternal mortality requires that more research should be done on adolescent health care, respectful maternal care, and (preventive) care for women during pregnancy, delivery, and in the puerperium.

Figure 4. Continuum of care for maternal, newborn and child health



Reference: Kerber, KJ, de Graft-Johnson, JE, Bhutta, ZA, Okong, P, Starrs, A, Lawn J. Continuum of care for maternal, newborn, and child health: from slogan to service delivery. *Lancet.* 2007;370:1358-1369

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10

Summary
Samenvatting

"*Alon Alon angger kelakon*"
(slowly but for sure)
A Javanese proverb

SUMMARY

This thesis describes how healthcare providers' ownership combined with government commitment can improve the maternal death surveillance and response (MDSR) cycle, aimed to reduce maternal deaths in Suriname. The prevalence, causes, and substandard care factors of maternal mortality were studied. Specific areas of substandard care could be identified and some recommendations from these studies were followed upon by response ("interventions") and monitoring of response.

Chapter 1 is the introduction, puts maternal mortality in context and contains the objectives of this thesis. The maternal death surveillance and response (MDSR) cycle and the concept of obstetric transition is explained. Besides, a brief overview is given of the health system in Suriname, and the influence of the country's economic situation.

In **Chapter 2** the history of maternal death surveillance and the implementation of MDSR in Suriname is described. The Ministry of Health (MOH) developed several programs to improve surveillance and initiate maternal death review (MDR); however, no implementation was yet in place in 2015. Driven by experiences from medical practice, we conducted the second confidential enquiry into maternal deaths between 2010 and 2014. With fundamentals from this study, the process to fulfill the MDSR cycle was initiated in 2015 by consistently reviewing the maternal deaths. We discussed the progress and the pitfalls in implementing the MDSR cycle. This implementation process of MDSR in Suriname, intended to reduce preventable maternal deaths, forms the basis of this thesis, which started with the 2010 - 2014 study described in Chapter 3.

In **Chapter 3** the 2010 - 2014 Reproductive Age Mortality Survey (RAMoS) in Suriname is reported. Various methods were used to capture maternal deaths followed by audits and substandard care analysis. The MMR was 130, underreporting was due to misclassification in 65% and misidentification in 26%.

Social insurance was an indicator of poverty and was found in 69% of the maternal deaths, in contrast to 44% of the general population. Besides, there was a difference in ethnicity in the general female population (Hindustani 28%, Maroon 24%, mixed 14%) compared to the maternal deaths (Hindustani 18%, Maroon 37%, mixed 8%). Audits performed by an expert committee classified the maternal deaths as direct in 63% (n=41/65), indirect in 32% (n=21/65) and unspecified in 5% (n=3/65). Main underlying causes were sepsis (27%, n=17/65), obstetric haemorrhage (20%, n=13/65) and hypertensive disorders (14%, n=9/65). Substandard care was mostly from third delay (inadequate care in the health facilities).

In **Chapter 4** the difficulties and challenges are evaluated in the analysis and classification of maternal deaths according to the WHO International Classification of Diseases-Maternal Mortality (ICD-MM). Auditing maternal deaths between 2010 and 2014 in Suriname learned that it was not always easy to attribute an underlying cause and consequently classify the death. We explored this by comparing the analysis of the attending physicians with the analysis of the Surinamese MDR committee. In 47% underlying causes determined by the attending physicians and the MDR committee differed. In addition, experienced MDR committees from Jamaica and the Netherlands analyzed the same cases from the 2010 - 2014 RAMoS, and a comparison was made with the analysis of the Surinamese MDR Committee. There was a better mutual agreement between the Surinamese and Jamaican MDR committee (κ=0.69) than between the Surinamese and the Dutch committee (κ=0.48). Agreement on the underlying cause category was best for abortive outcomes (κ=0.85) and obstetric haemorrhage (κ=0.74) and worst for unspecified (κ=0.29) and other direct causes (κ=0.32). The MDR committee of the Netherlands classified more cases as “unspecified”, especially cases lacking confirmatory diagnostic tests. The cases classified as “other direct obstetric causes” were characterised by either multiple comorbid conditions or rapidly developing complications. Specific challenges applying ICD-MM included attribution of underlying cause when co-morbidities occur, inclusion of suicides

in early pregnancy, and maternal deaths occurring outside the country of residence.

In **Chapter 5** an in-depth analysis of the most frequent cause of maternal deaths is performed between 2010 and 2014, namely obstetric and non-obstetric sepsis (45% (n=29/65) sepsis-related maternal deaths). In 27% (n=17/65) sepsis was the underlying cause of death, in five women sepsis was the mode of death while sepsis contributed to death in seven women. Non-obstetric sepsis occurred more frequently (n=13/65), mostly caused by pneumonia. Most deaths occurred postpartum (n=21/27) and within one week. Substandard care was identified in 93% (n=25/29) of the sepsis-related deaths. Third delay contributed to death in 89% (n=24/29), while second delay only in 15% (n=4/29). Delayed monitoring and diagnosis of sepsis was followed by delayed therapy. In 88% (n=15/17), women had signs of severe sepsis when arriving at the hospital; however, antibiotic treatment was not started within one hour.

One of the recommendations of the 2010-2014 RAMoS was to develop and implement national guidelines on postpartum haemorrhage (PPH) and eclampsia.

In **Chapter 6** the focus is on the response upon this recommendation. The process of the bottom-up development of two context-tailored national obstetric guidelines on PPH and hypertensive diseases in pregnancy (HDP) in Suriname in 2016 was described extensively. First, a situation analysis was performed to determine the standard of care at that time. Subsequently, international guidelines were reviewed, and a primary set of guidelines was developed. These initial versions were reviewed by local and international experts, and a four-day conference initiated a national discussion by an estimated 200 obstetric healthcare providers and policymakers. During the congress, the guidelines were adapted and to practice and evaluate the content of the guideline's simulation-based trainings were held. Obstetric health care providers had the opportunity to comment on the guidelines until six weeks after the conference. Finally, the guidelines were

distributed, and in the future implementation must be evaluated. In 2019 the second national obstetric conference concentrated on the evaluation of these two guidelines, development of other relevant guidelines (sepsis, postnatal care, sickle cell disease) and obstetric emergency training.

The 2010-2014 RAMoS reported that obstetric haemorrhage was the most frequent direct cause of maternal deaths (20%, n=13/65), mostly (n=11/13) from PPH. However, studies on the burden of PPH in Suriname lacked and it was unclear how and if the recently developed national PPH guidelines were used in practice.

Therefore, in **Chapter 7**, we studied the magnitude of PPH in Suriname in 2017, including prevalence, risk factors, and causes. We performed a criteria-based audit to analyze the PPH management and to evaluate adherence to the national guidelines. The prevalence of PPH in Suriname was 9.2%, similar to international and regional reports. Interhospital prevalence, however, varied substantially due to 1) inconsistent determination of the amount of blood loss 2) differences in maternal and perinatal characteristics and 3) variable guideline adherence. Significant risk indicators were being of African descent, multiple pregnancy, hospital of delivery, preterm birth, caesarean section, macrosomia, and stillbirths. At least one risk indicator was present in 80% of women with PPH, but also in 70% of women without PPH, indicating the weak discriminative ability of risk indicators. Underlying causes were mainly uterine atony (57%, n=102/180) and retained placenta (19%, n=35/180). Active management of third stage of labor (AMTSL) includes PPH prevention with oxytocin, a uterotonic drug, in every delivery. Oxytocin was inadequately given for prevention (in 62%) and therapy (in 69%). Tranexamic acid, an antifibrinolytic drug, was given in only 5%, but advised nowadays as part of the first-line treatment for PPH.
Another recommendation of the 2010-2014 RAMoS was the installation of a maternal death committee to review every maternal death consistently. We took

the lead in installation of the national MDR committee (MAMS) in 2015, and since then every maternal death is reviewed.

In **Chapter 8** five years of maternal death audits in Suriname is assessed and this is compared with previously performed studies as the 1991-1993 confidential enquiry into maternal deaths (CEMD I) and the 2010-2014 RAMoS (CEMD II). There were 62 maternal deaths (MMR 127/100.000 live births), and the underreporting rate was 24% in 2015-2019 (CEMD III). Maternal deaths were more frequently in women of African descent (63%), multipara (46%), occurred postpartum (76%) and in the hospitals (77%). Women either attended health facilities in bad medical condition (23%, n=14/62) or died at home or during transportation (18%, n=11/62). Eight (67%) of the twelve late maternal deaths, had primary underlying causes originating in pregnancy or within 42 days postpartum.
Analyzing the trend in maternal deaths showed: 1) declining MMR (226 vs 130 vs 127) and underreporting rate (62% vs 26% vs 24%), 2) significantly less women died in the rural interior [22%(n=14/64) vs 6%(n=4/65) vs 7%(n=4/62)], and 3) more deceased women lacked insurance [9%(n=6/64) vs 0 vs 25%(n=15/59)], respectively in CEMD I, II, III. Postmortem autopsies were performed in only 3%(n=2/65) in CEMD II and 5%(n=3/62) in CEMD III. There was a decrease in obstetric haemorrhage (30% vs 20% vs 11%), while abortion-related deaths (3% vs 3% vs 6%) increased. Also, unspecified deaths [2%(n=1/64) vs 5%(n=3/65) vs 18%(n=11/62)], and suicide occurred more frequently in CEMD III (0 vs 2% vs 8%). Substandard care analysis showed similar trends over the years, with predominantly phase three delay and no significant difference in phase one delay.

Chapter 9 is the general discussion of this thesis. It describes Suriname's progress in maternal mortality reduction, the implementation of MDSR and the obstetric transition of Suriname. Besides, the continuum of care is discussed, and the holistic approach considering maternal mortality as a component of maternal health in general.

NEDERLANDSE SAMENVATTING

Dit proefschrift beschrijft het implementatie proces van moedersterfte surveillance en respons (MDSR) in Suriname met als primaire doel de reductie van voorkombare moedersterfte. Het proefschrift laat zien dat de betrokkenheid van zorgverleners en samenwerking met beleidsmakers van essentieel belang is. Onderzoek laat specifieke hiaten zien in de kwaliteit van de zorg voor vrouwen tijdens de zwangerschap en postpartum. Hierdoor kunnen doelgerichte aanbevelingen worden gedaan om moedersterfte te voorkomen. Dit proefschrift beschrijft deze onderzoeken en de interventies gebaseerd op deze aanbevelingen.

Hoofdstuk 1 is de introductie en maternale sterfte in Suriname wordt in context gebracht met de wereldwijde en regionale situatie. De maternale sterfte surveillance en response (MDSR) cyclus, bedoeld om voorkombare maternale sterfte te elimineren en het concept van obstetrische transitie worden belicht. Daarnaast wordt een overzicht gegeven van het gezondheidssysteem in Suriname en de invloed van economische op de maternale gezondheidszorg en sterfte.

Hoofdstuk 2 geeft een historisch overzicht van MDSR in Suriname en beschrijft onze bijdrage in het implementatieproces. Eerst wordt de geschiedenis belicht van maternale sterfte surveillance en registratie. Het Ministerie van Volksgezondheid (MVG) heeft verschillende documenten en projecten beschreven om het proces van MDSR te verbeteren, echter in 2015 was implementatie daarvan was nog niet van de grond gekomen. Vanuit de ervaringen van de kliniek hebben wij als onderzoekers besloten een onderzoek te verrichten naar moedersterfte tussen 2010 en 2014. Met aanbevelingen van deze studie als basis, hebben wij samenwerking gezocht met het MVG en het Bureau voor Openbare Gezondheidszorg (BOG) om het proces van implementatie van de MDSR cyclus in te zetten. Dit hoofdstuk beschrijft het proces en de belemmeringen die hierbij zijn (en nog steeds worden) ondervonden. Tevens wordt een plan beschreven om in de toekomst in Suriname deze totale cyclus te kunnen vervolmaken.

In **Hoofdstuk 3** wordt het landelijk onderzoek in Suriname naar maternale sterfte de periode 2010 - 2014 beschreven. Deze studie vormt de basis van dit proefschrift. De maternale sterfte ratio (MMR) bedroeg 130 per 100.000 levendgeborenen (n=65). De belangrijkste oorzaken waren sepsis en fluxus. Tevens droegen hypertensieve aandoeningen bij aan 30% van alle moedersterfte. Bijna de helft van de maternale sterfte was te voorkomen. De belangrijkste substandaard factor betrof de kwaliteit van zorg en betrof o.a. vertraging in het stellen van de diagnose en de behandeling. De aanbevelingen waren om de surveillance te verbeteren, landelijke richtlijnen te ontwikkelen (Hoofdstuk 6) en een nationale maternale sterfte audit commissie (MaMS) te installeren om consistent maternale sterfte audits te doen (Hoofdstuk 8).

In **Hoofdstuk 4** worden de problemen besproken bij de analyse en classificatie van alle zwangerschap gerelateerde sterfte van 2010 - 2014 volgens de Internationale Classificatie van Ziekten - Maternale Mortaliteit (ICD-MM). Er was een verschil tussen de doodsoorzaak vastgesteld door de behandelende arts en de audit commissie in 47% van de moedersterfte in die periode. Classificatie tussen de audit commissies van Nederland, Jamaica en Suriname werd vergeleken. In 15% was er contradictie tussen de commissies of de sterfte maternaal of 'toevallig' was. Sterfte werd vaker als 'niet gespecificeerd' door Nederland (19%) geduid, dan door Jamaica (7%) en Suriname (4%). We beschrijven de problemen waar de drie landen ICD-MM tegenaan liepen bij gebruik van de ICD-MM met als doel bij te dragen aan de mogelijke revisies in de toekomst om vergelijkingen in en tussen landen te verbeteren.

In **Hoofdstuk 5** worden de sepsis-gerelateerde maternale sterfte in Suriname van 2010 - 2014 (n=29) geanalyseerd. De belangrijkste onderliggende oorzaak was een pneumonie (n=14, 48%). Geen van de vrouwen ontvingen binnen het eerste uur nadat de diagnose sepsis was vastgesteld antibiotica behandeling. Andere belangrijke factoren die tot de dood leidden, waren slechte monitoring (59%) en vertraging in het stellen van de diagnose (63%). Verduidelijking van de diagnose

'maternale sepsis' zou helpen om sneller de diagnose te stellen. Hierdoor kan antibiotica binnen het eerste uur gestart worden (het 'gouden uur'), en kan daardoor sepsis-gerelateerde sterfte verminderen.

In **Hoofdstuk 6** wordt een van de aanbevelingen nl. het ontwikkelen van landelijke richtlijnen besproken. De zogenaamde 'bottom-up' aanpak werd in Suriname gebruikt voor het ontwikkelen van lokale richtlijnen (fluxus en hypertensieve aandoeningen), en was aangepast aan de lokale context. De belangrijkste factor die positief heeft bijgedragen was de sterke betrokkenheid van lokale zorgverleners. Discrepanties tussen internationale aanbevelingen zorgden dat draagvlak pas kon worden gecreëerd na lokale consensus. Laag en middeninkomenslanden worden aanbevolen zelf 'bottom-up' richtlijnen te ontwikkelen om betere implementatie te bewerkstelligen.

Hoofdstuk 7 bevat een beschrijvende studie over fluxus postpartum in Suriname in 2017, kort na de introductie van de landelijke richtlijn. De prevalentie was 9% (n=808), vergelijkbaar met de wereldwijde prevalentie, echter met grote variatie tussen ziekenhuizen (4-12%). Het bloedverlies kwam niet goed overeen met de ernst (bloedtransfusies, IC-opname), wat duidt op onbetrouwbare schattingen van het bloedverlies. We onderzochten tevens in welke mate de richtlijn werd gebruikt door een audit te doen gebaseerd op de recente richtlijn. Oxytocine preventie bleek slechts in 62% toegediend te zijn bij vrouwen met een ernstige fluxus en tranexaminezuur werd in slechts 5% van de vrouwen met een ernstige fluxus gegeven. Door de identificatie en aanpakken van deze hiaten in de zorg, kunnen gerichte interventies de fluxus uitkomsten doen verbeteren.

In **Hoofdstuk 8** worden vijf jaren van maternale sterfte audits door de commissie MaMS geanalyseerd (2015-2019). Hiermee is een van de belangrijkste aanbevelingen uit de 2010 - 2014 studie opgevolgd. Er waren 62 gevallen van moedersterfte en de maternale mortaliteit ratio (MMR) was 127 per 100.000 levendgeborenen. Moedersterfte kwam meer voor in vrouwen van Afrikaanse

afkomst, multipara, en vond postpartum en in de ziekenhuizen plaats. Bijna ¼ van de overleden vrouwen in deze periode kwamen in kritieke toestand aan in de ziekenhuizen of poliklinieken en een vijfde stierf al thuis of tijdens transport. Van de twaalf gevallen van late maternale sterfte waren er acht waarbij de vrouwen reeds tijdens de zwangerschap symptomen hadden ontwikkeld van de ziekte waaraan ze uiteindelijk waren overleden.
Er was ook een trendanalyse verricht, waarbij de drie studies die maternale mortaliteit in Suriname hebben onderzocht (1991-1993, 2010 - 2014, 2015 - 2019), werden vergeleken. Deze liet zien dat de MMR afnam in de tijd, evenals de ernst van de onderrapportage. Het percentage onverzekerde vrouwen was het hoogste in de laatste studie. Obducties werden zelden gedaan. Moedersterfte veroorzaakt door postpartum bloedingen verminderden terwijl abortus gerelateerde sterfte, sterfte door suïcide en hypertensieve aandoeningen toenamen. Er was ook een hoger percentage niet gespecificeerde sterfte, waarbij de onderliggende oorzaak onduidelijk was. Substandaard zorg werd voornamelijk veroorzaakt door zorg onder de maat in de ziekenhuizen, echter de slechte toegankelijkheid van de zorg is in de loop der jaren ook niet verbeterd ondanks betere wegen en de beschikbaarheid van meer faciliteiten. Mogelijk dat de toename van het aantal onverzekerden invloed had op de zorgvraag van de zwangere vrouw.

Hoofdstuk 9 is de algemene discussie en beschrijft de MMR van Suriname in relatie tot de wereldwijde en regionale MMR. Suriname ' s voortgang in de implementatie van MDSR sinds de studies en interventies zoals beschreven in deze thesis zijn doorgevoerd, worden uitvoerig belicht. Tevens wordt de obstetrische transitie van Suriname besproken in relatie tot andere Latijns Amerikaanse landen. Tenslotte wordt moedersterfte besproken vanuit de optiek van de "continuüm of care", een continue cyclus die de maternale gezondheidszorg beschouwd in zijn totaliteit waarbij behalve specifieke obstetrische zorg, ook de algehele lichamelijke en geestelijke gezondheid van de vrouw en toegang tot (respectvolle) zorg belangrijk is.

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In my career as a medical doctor becoming a gynecologist, you played a central role. For many years we had several ideas about doing research. In 2015, you sent a very talent medical student (Kim) to assist me in research on maternal mortality (which, in fact, I only had the intention to do at that time). I could have never imagined at that time that this would be the start of an academic process in which you encouraged and supported me, unconditionally. Thank you for always being there and for believing in me.

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Starting this journey together back in 2015, I would never guess that this would be a lifelong collaboration. We went through rough waters, and although we did not intend to do a PhD in the first instance, I am very proud of what we were able to achieve together. We were driven by our determination to fight injustice. Your dedication and persistence serve as an example. Thank you for everything you have done and still do, unconditionally and voluntarily, for the Surinamese women!

∞∞

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Knowing you already from my specialization as a gynaecologist in Leids Universitair Medical Center (LUMC), our roads met again seven years later because you were the upcoming chair of the maternal mortality committee in the Netherlands. This period coincides with your shift to Universal Medical Center Utrecht, where I got the opportunity to do this PhD under your supervision. Also, allowing me to share my work with students all over the world during the summer school since 2016 was a great experience, which I hope I can continue.

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Karansing, Ray Tjon Kon Fat and Ramon Tjon A Fat), I am very grateful that you all participated and supported this research. As a group, we already do a lot in individual patient care. This thesis has a more epidemiologic approach and highlights the specific gaps in care. I hope that together we can continue improving the quality of care and the M(P)DSR implementation to reduce maternal (and perinatal) deaths in the future.

∞∞

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∞∞

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About the author

Lachmi Reshma Kodan was born on October 22nd, 1976 in ‘s Lands Hospital in Paramaribo as the daughter of Kodan, Hasmechandre and Karaya, Dhoeknie. She lived in Nickerie, the district at the Western border of Suriname, where she completed primary school (Kartini school) and high school (Schneiders Howard Mulo School and VWO Nickerie). To continue with her study at the Medical Faculty of Anton de Kom University of Suriname she had to move to Paramaribo. Lachmi graduated cum laude in March 2003 as a medical doctor and continued with her specialization as an obstetrician/gynaecologist at Academisch Ziekenhuis Paramaribo (AZP), Groene Hart Ziekenhuis Gouda and Leids Universitair Medisch Centrum in the Netherlands. In 2009 she started working as an obstetrician/gynaecologist in Academisch Ziekenhuis Paramaribo and became Head of the Department of Obstetrics & Gynecology in 2011. In the past four years, she pursued a PhD at the Department of Obstetrics at the Universitair Medisch Centrum Utrecht (UMCU). She was financially supported by the UMCU global support program to do this PhD and a Master of Science degree in Clinical Epidemiology at the University of Utrecht, which she completed in July 2020.

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[1] Equal contribution, shared first authorship

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Safe Motherhood Series

The Dutch Working Party 'International Safe Motherhood and Reproductive Health' aims to contribute to improvement of the reproductive health status of women around the globe, in particular by collaborating with local health workers (http://www.safemotherhood.nl). The Working Party is part of both the Dutch Society of Obstetrics and Gynaecology (NVOG) and the Dutch Society for International Health and Tropical Medicine (NVTG). The activities that are undertaken under the umbrella of the Working Party can be grouped into four pillars: education, patient care, research and advocacy.

Research activities are undertaken by (medical) students, Medical Doctors International Health and Tropical Medicine and many others. Some research activities develop into PhD-trajectories. PhD- candidates all over the world, Dutch and non-Dutch, work on finding locally acceptable and achievable ways to improve the quality of maternal health services, supervised by different members of the Working Party. Professor Jos van Roosmalen initiated the Safe Motherhood Series, which started in 1995.

THE SAFE MOTHERHOOD SERIES

- The role of oral (methyl)ergometrin in the prevention of postpartum haemorrhage. (**Akosua de Groot**), Radboud UMC, Nijmegen, the Netherlands, 1995
- Perinatal assessment in rural Tanzania. (**Gijs Walraven**), Radboud UMC, Nijmegen, the Netherlands, 1995
- Confidential enquiries into Maternal Deaths in the Netherlands, 1983- 1992. (**Nico Schuitemaker**), UMC Leiden, the Netherlands, 1998
- Confidential enquiries into Maternal Deaths in Surinam. (**Ashok Mungra**), UMC Leiden, the Netherlands, 1999
- Reproductive health matters in rural Ghana. (**Diederike Geelhoed**), UMC Leiden, the Netherlands, 2003

- Vaginal birth after caesarean section in Zimbabwe and The Netherlands (**Wilbert Spaans**), AMC Amsterdam, the Netherlands, 2004
- Safe Motherhood and Health systems research: Health care seeking behaviour and utilization of health services in Kalabo District (**Jelle Stekelenburg**), VU Amsterdam, the Netherlands, 2004
- Enhancing survival of mothers and their newborns in Tanzania (**Godfrey Mbaruku**), Karolinska Institute, Stockholm, Sweden, 2005
- Beyond the numbers: confidential enquiries into maternal deaths in Accra-Ghana (**Afisah Yakubu Zakariah**), Vrije Universiteit Brussel, Belgium, 2008
- Severe maternal morbidity in the Netherlands: the LEMMoN study (**Joost Zwart**), UMC Leiden, the Netherlands, 2009
- Obstetric audit in Namibia and the Netherlands (**Jeroen van Dillen**), VU Amsterdam, the Netherlands, 2009
- Confidential enquiries into maternal deaths in the Netherlands 1993- 2005 (**Joke Schutte**), VU Amsterdam, the Netherlands, 2010
- Delay in Safe Motherhood (**Luc van Lonkhuijzen**), UMC Groningen, the Netherlands, 2011
- Medical Mirrors: Maternal care in a Malawian district (**Thomas van den Akker**), VU University Medical Centre, Amsterdam, the Netherlands, 2012
- Leading change in the maternal health care system in Tanzania: application of operations research (**Angelo Nyamtema**), VU Amsterdam, the Netherlands, 2012
- Health professionals and maternal health in Malawi: mortality and morbidity at district level (**Jogchum Beltman**), VU Amsterdam, the Netherlands, 2013
- Obstetric emergencies in primary midwifery care in the Netherlands (**Marrit Smit**), UMC Leiden, the Netherlands, 2014
- Improving maternal outcome in rural Tanzania using obstetric simulation-based training (**Ellen Nelissen**), VU Amsterdam, the Netherlands, 2014
- The aberrant third stage of labour (**Giel van Stralen**), UMC Leiden, the Netherlands, 2015

- Terugvinden van waardigheid, community-based sociotherapie in Rwanda, Oost-Congo en Liberia (**Cora Bakker**), VU Amsterdam, the Netherlands, 2016
- Severe acute maternal morbidity, risk factors in the Netherlands and validation of the WHO Maternal Near-Miss Tool (**Tom Witteveen**), UMC Leiden, the Netherlands, 2016
- Getting the job done, providing lifelong HIV-treatment in settings with limited human resources for health: innovative approaches (**Marielle Bemelmans**), VU Amsterdam, the Netherlands, 2016
- Identifying needs for optimizing the health work force in Ethiopia (**Tegbar Yigzaw Sindekie**), VU Amsterdam, the Netherlands, 2017
- Improving frontline health workers' performance in low resource settings; the case of Ethiopia (**Firew Ayalew Desta**), VU Amsterdam, the Netherlands, 2017
- Increasing access to anaesthesia in Ethiopia: task shifting (**Sharon Kibwana**), VU Amsterdam, the Netherlands, 2017
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- Assisting birth attendants in providing acceptable care under unacceptable clinical realities: The Partoma Intervention Study at Zanzibar's Tertiary Hospital (**Nanna Maaløe**), University of Kopenhagen, Denmark, 2019
- Severe Maternal Morbidity and Mortality in Eastern Ethiopia (**Abera Kenay Tura**), UMC Groningen, the Netherlands, 2019
- Maternity Waiting Homes in Ethiopia to improve women's access to maternity care (**Tienke Vermeiden**), UMC Groningen, the Netherlands, 2019
- Improving access to quality maternal and newborn care in lowresource settings: the case of Tanzania (**Dunstan Raphael Bishanga**), UMC Groningen, the Netherlands, 2019
- Towards better prognostic and diagnostic strategies for major obstetric haemorrhage (**Ada Gillissen**), Leiden University Medical Centre, the Netherlands, 2019

- Hospital based audit of obstetric care and birth preparedness in rural Rwanda (**Richard Kalisa**), VU University Amsterdam, the Netherlands, 2019
- Re-introduction of vacuum extraction in a tertiary referral hospital in Uganda (**Barbara Nolens**), VU University Amsterdam, the Netherlands, 2019
- Health system determinants of maternal and neonatal health in Rwanda (**Felix Sayinzoga**), Radboud UMC, Nijmegen, the Netherlands, 2019
- Context-appropriate innovative solutions for improving the access to quality intra- and immediate postpartum care in India (**Somesh Kumar**), UMC Groningen, the Netherlands, 2019
- Quality of maternal and newborn health care in health facilities in Afghanistan (**Nasratullah Ansari**), VU Amsterdam, the Netherlands, 2019
- Safe Motherhood: Improving the quality of maternal and perinatal health care in a rural hospital in Tanzania (**Rob Mooij**), UMC Groningen, the Netherlands, 2020
- Strategies to improve intrapartum care: foetal monitoring in low resource settings (**Natasha Housseine**), UMC Utrecht, the Netherlands, 2020
- Maternal mortality in Suriname: Implementation of Maternal Death Surveillance and Response to reduce preventable maternal deaths (**Lachmi Kodan**), UMC Utrecht, the Netherlands, 2020
- Maternal mortality, near-miss and stillbirths in Suriname: time to respond (**Kim Verschueren)**, UMC Utrecht, the Netherlands, 2020

Death during pregnancy, childbirth or postpartum is a tragedy. The establishment of the maternal death surveillance and response cycle is essential in reducing maternal deaths. This book presents ten years of maternal mortality in Suriname and highlights areas where improvements in care are necessary to reduce preventable maternal deaths. Based on the recommendations of maternal death reviews in Suriname, two interventions were implemented: the installation of a maternal death review committee and the development of national obstetric guidelines.