A global view of severe maternal morbidity: moving beyond maternal mortality

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Abstract

Background: Maternal mortality continues to be of great public health importance, however for each woman who dies as the direct or indirect result of pregnancy, many more women experience life-threatening complications. The global burden of severe maternal morbidity (SMM) is not known, but the World Bank estimates that it is increasing over time. Consistent with rates of maternal mortality, SMM rates are higher in low- and middle-income countries (LMICs) than in high-income countries (HICs).

Severe maternal morbidity in high-income countries: Since the WHO recommended that HICs with low maternal mortality ratios begin to examine SMM to identify systems failures and intervention priorities, researchers in many HICs have turned their attention to SMM. Where surveillance has been conducted, the most common etiologies of SMM have been major obstetric hemorrhage and hypertensive disorders. Of the countries that have conducted SMM reviews, the most common preventable factors were provider-related, specifically failure to identify “high risk” status, delays in diagnosis, and delays in treatment.

Severe maternal morbidity in low and middle income countries: The highest burden of SMM is in Sub-Saharan Africa, where estimates of SMM are as high as 198 per 1000 live births. Hemorrhage and hypertensive disorders are the leading conditions contributing to SMM across all regions. Case reviews are rare, but have revealed patterns of substandard maternal health care and suboptimal use of evidence-based strategies to prevent and treat morbidity.

Effects of SMM on delivery outcomes and infants: Severe maternal morbidity not only puts the woman’s life at risk, her fetus/neonate may suffer consequences of morbidity and mortality as well. Adverse delivery outcomes occur at a higher frequency among women with SMM. Reducing preventable severe maternal morbidity not only reduces the potential for maternal mortality but also improves the health and well-being of the newborn.

Conclusion: Increasing global maternal morbidity is a failure to achieve broad public health goals of improved women’s and infants’ health. It is incumbent upon all countries to implement surveillance initiatives to understand the burden of severe morbidity and to implement review processes for assessing potential preventability.
Background

Maternal mortality is a sentinel event used globally to monitor maternal health, the general quality of reproductive health care, and the progress countries have made toward international development goals [1, 2]. Globally, the maternal mortality ratio (MMR) dropped from 385 maternal deaths per 100,000 live births in 1990 to 216 in 2015, a 44% reduction [3]. Most high-income countries (HICs) have low maternal death rates, generally ranging from 3 to 12 per 100,000, that have consistently decreased in the last 25 years [4]. The United States is an exception with an MMR of 14 per 100,000, a 16.7% increase since 1990 [4]. Low and middle-income countries (LMICs) still bear 99% of the burden of maternal mortality and the majority of deaths occur in sub-Saharan Africa [3]. A Sustainable Development Goal for 2030 is to reduce the global MMR to 70 per 100,000 births and for no country to exceed two deaths that ratio (140 per 100,000).

Globally, more than half of maternal deaths between 2003 and 2009 were due to hemorrhage, hypertensive disorders, and sepsis [5]. Common causes of maternal mortality varied by region: in Northern Africa, 36.9% of deaths were due to hemorrhage compared with 16.3% in HICs [5]. Deaths due to hypertensive disorders were most common in Latin America and the Caribbean, accounting for 22.1% of deaths [5]. The vast majority of deaths due to sepsis were in LMICs [5].

Maternal mortality continues to be of great public health importance, however for each woman who dies as the direct or indirect result of pregnancy, many more women experience life-threatening complications [6, 7]. It is estimated that 50–100 women experience severe morbidity (SMM) compared to every maternal death in the United States and the rate has more than doubled from 74 per 10,000 delivery hospitalizations in 1998–99 to 163 in 2010–11 [2, 7]. Consistent with rates of maternal mortality, SMM rates are higher in LMICs than in HICs, complicating up to 8% of deliveries that take place in hospitals [8, 9]. These alarming rates and their implications for poor maternal and infant outcomes with long-term poor health consequences, highlight a critical need for surveillance with the goal of understanding how to prevent SMM through quality improvement initiatives. Maternal pregnancy outcomes can be conceptualized on a continuum of severity: normal/healthy pregnancy -> morbidity -> severe morbidity -> death [10]. Women with severe maternal morbidity experience severe pregnancy, delivery, and postpartum complications such as massive hemorrhage, cardiac arrest, organ system failure, stroke, and other health problems that may result in extended hospital stay, massive transfusion, hysterectomy, major surgery, or other major medical interventions [11]. The study of SMM provides opportunities to see a fuller picture of the quality of maternity care, potentially identifying factors associated with preventing the progression along the continuum to severe morbidity or death [2, 12]. As SMM emerges as an important area of increased interest globally, it is clear that the issues and solutions in LMICs are very different from those in HICs. This review presents current literature on SMM globally, first in HICs and then in LMICs.

Severe maternal morbidity in high-income countries

High-income countries (HICs) are increasingly focused on SMM in addition to maternal mortality [13–15]. Given the rarity of maternal mortality in HICs, routine surveillance for SMM is now recommended to monitor maternal health and quality of care [9]. Estimates of the prevalence of SMM in the HICs depend on the way SMM is defined (Table 1). EURO-PERISTAT, a 20-year collaboration of 15 European countries focused on developing indicators of perinatal health, defined SMM as a composite of the rates of eclampsia, hysterectomy for postpartum hemorrhage, ICU admission, blood transfusion, and uterine artery embolization [13].

More recently, the EPIMOMS study group in France proposed a comprehensive set of 17 indicators specifically for use in HICs [16]. Their definition includes the EURO-PERISTAT indicators as well as measures of organ system dysfunction defined by minimal management-based criteria [16]. Both the EURO-PERISTAT and EPIMOMS definitions are based on data from existing sources such as hospital administrative records and laboratory tests. Similarly, in the United States, the CDC has published a list of 18 indicators and corresponding ICD codes using the 10th revision of the International Classification of Disease (ICD-10) to facilitate the identification of SMM using hospital discharge data [17, 18].

To move beyond a list of indicators and to define a composite indicator that could easily identify SMM from routinely collected population health data, researchers in Australia began with a list of 86 diagnoses and procedures that could potentially be included in the final composite [19]. To refine the components of the indicator, a validation study was conducted to assess whether cases that screened positive for SMM were true cases based on medical record review. The final SMM indicator comprised 14 diagnoses and 11 procedures with a positive predictive value of 94.6%, sensitivity of 78.4%, and specificity of 99.9% for confirmed SMM as identified by medical record review, the gold standard definition [19]. This indicator was adapted for use in England, taking into account limitations of the quality and reliability of English hospital data [20].

Departing from efforts to define SMM using information available in routinely collected administrative data, representatives from the 13 HICs in the International
| Author (Year) | Country | Definition of SMM | Estimated Prevalence | Leading Causes |
|--------------|---------|-------------------|----------------------|----------------|
| Bouvier-Colle (2012) [13] | 17 EU Countries | Eclampsia | 0.2–1.6 | Obstetric hemorrhage (65.2%), hypertensive conditions (21.6%) |
| | 3 EU Countries | ICU Admission | 0.5–3.1 | | |
| | 10 EU Countries | Blood Transfusion | 0.1–11.5 | | |
| | 15 EU Countries | Hysterectomy | 0.2–1.0 | | |
| | 7 EU Countries | Embolisation | 0.0–0.3 | | |
| Colmorn (2015) [71] | Denmark, Finland, Iceland, Norway, and Sweden | Complete uterine rupture | 5.6 | Obstetric hemorrhage |
| Deneux-Tharaux (2017) [16] | France | Obstetric hemorrhage, hypertensive complications, Psychiatric disorder, decompensation of preexisting condition, pulmonary embolism, sepsis, stroke, amniotic fluid embolism, other | 13.9 | Obstetric hemorrhage (65.2%), hypertensive conditions (21.6%) |
| | | | | |
| Jayaratnam (2016) [45] | Australia | WHO criteria | 4.8 | Hemorrhage |
| Jayaratnam (2011) [72] | Australia | Antepartum hemorrhage requiring emergency surgery, PPH requiring surgery, any postnatal patient requiring surgery, severe pre-eclampsia/eclampsia/HELLP, ICU admission, shock, acute ruptured ectopic, pulmonary embolism, other conditions requiring immediate medical assessment | 6.0 | | |
| Kilpatrick (2016) [43] | United States | CDC method with chart review to confirm condition was truly life-threatening | 7.3 | Hemorrhage, hypertensive disorders |
| Lawton (2016) [personal communication] | New Zealand | ICU/HDU admission | 6.2 | Major blood loss, pre-eclampsia, sepsis |
| Lyndon (2012) [73] | United States | CDC method supplemented with birth certificate data | 5.8 | | |
| Main (2016) [74] | United States | “Gold standard” clinical guidelines | 7.3 | Major obstetric hemorrhage, ICU/coronary care admission |
| Marr (2014) [40] | Scotland | Major obstetric hemorrhage, eclampsia, renal or liver dysfunction, pulmonary edema, acute respiratory distress, coma, cerebrovascular event, status epilepticus, anaphylactic shock, septicemic shock, anesthetic problem, massive pulmonary embolism, ICU/coronary care unit admission | 6.1 | | |
| Nair (2016) [20] | England | Acute abdomen | 0.01 | | |
| | | Acute renal failure | 0.08 | | |
| | | Acute psychosis | 0.05 | | |
| | | Cardiac arrest/failure or infarction | 0.05 | | |
| | | Cerebral edema or coma | 0.01 | | |
| | | DIC | 0.01 | | |
| | | Cerebrovascular accident | 0.04 | | |
| | | Major complications of anesthesia | 0.06 | | |
| | | Obstetric embolism (inc. AFE) | 0.27 | | |
| | | Shock | 0.20 | | |
| | | Sickle cell crisis | 0.05 | | |
| | | Status asthmaticus | 0.02 | | |
| | | Status epilepticus | 0.03 | | |
| | | Uterine rupture | 0.48 | | |
| | | Eclampsia | 0.71 | | |
| | | Sepsis | 0.44 | | |
| | | Cerebral venous thrombosis | 0.003 | | |
Network of Obstetric Surveillance Systems (INoSS) developed consensus definitions for eight severe morbidity conditions: eclampsia, amniotic fluid embolism, pregnancy-related hysterectomy, severe primary postpartum hemorrhage, uterine rupture, abnormally invasive placentation, spontaneous hemoperitoneum in pregnancy, and cardiac arrest in pregnancy [21]. Multidisciplinary panels used an iterative process to produce standardized definitions to promote comparability across countries. Clinical data is required to apply these definitions, necessitating additional data collection systems for their use [21].

Case review has long been the gold standard for assessing maternal deaths for the underlying cause of death, the factors that contributed to the progression from morbidity to death, and to determine whether the death was potentially preventable [22–25]. Reviews for potential preventability have provided valuable insights into opportunities to improve obstetrical care and management and identify themes and trends in preventability factors and translate these findings into action [26–30]. As attention in HICs moves to SMM, there have been initiatives to institute SMM case review as well [15, 24, 31]. For the purposes of case assessment, preventability can be defined as “any action or inaction on the part of the health care provider, system, patient, or a combination of these factors that may have caused progression to more severe morbidity” [32]. In other words, did the woman have to get as sick as she did? In addition to identifying factors that contributed to the progression to severe morbidity, SMM reviews may assist facilities in recognizing evidence-based practices that prevent maternal death, as women with SMM may survive because of medical intervention and best clinical practice.

The US Centers for Disease Control and Prevention (CDC) and the American College of Obstetricians and Gynecologists (ACOG) have called for greater monitoring and review of severe pregnancy and delivery complications, and also provided detailed recommendations for doing so [11, 15, 31]. The CDC and ACOG specifically recommend facility-level multidisciplinary review of all cases by using a two-factor scoring system that identifies SMM cases by: (1) admission to the intensive care unit (ICU) and/or (2) transfusion of four or more units of blood products at any time from conception through 42 days postpartum [33–35]. This 2-factor scoring system developed by Geller et al. has been validated and can be used in real time in hospital settings, unlike administrative datasets used for population-level surveillance [33, 34, 36]. To date, SMM reviews have been implemented in individual facilities in California [37] and Illinois recently piloted a statewide implementation through its regionalized perinatal system [38].

### Table 1 Estimates of the Prevalence of Severe Maternal Morbidity in High-Income Countries (Continued)

| Author (Year) | Country | Definition of SMM | Estimated Prevalence* | Leading Causes |
|---------------|---------|------------------|-----------------------|---------------|
| O'Malley (2016) [75] | Ireland | WHO criteria | 0.15 | Hemorrhage |
| Ozimek (2016) [37] | United States | “Gold standard” clinical guidelines from Main (2016) | 0.01 | Hemorrhage, preeclampsia/eclampsia |
| Zanconato (2012) [44] | Italy | ICU admission, transfusion ≥4 units, emergency peripartum hysterectomy, arterial embolization | 0.50 | Hypertensive disorders, hemorrhage, sepsis |
| Zwart (2010) [76] | The Netherlands | ICU admission, eclampsia/HELLP syndrome, uterine rupture, major hemorrhage, miscellaneous | 0.24 | Hypertension |
| | | Peripartum hysterectomy | 0.31 | |
| | | Abnormally invasive placenta | 0.31 | |
| | | Severe hemorrhage at delivery | 0.31 | |

*Per 1000 live births
New Zealand adapted the Illinois model for their research and, with support from the New Zealand Ministry of Health, implemented multidisciplinary regional panels across the country to review cases of all women admitted to an ICU or high-dependency unit who were pregnant or within 42 days of delivery. The national rate of women with SMM admitted to an ICU/HDU was 6.2 per 1000 live births. Of those 399 cases reviewed, 34% were deemed potentially preventable, 29.5% were classified as not preventable but improvement in care was needed. Factors associated with preventable SMM cases, were provider (clinician) related in almost all cases (93.4%), most often issues related to diagnosis (inappropriate or delay in diagnosis or failure to recognize “high risk” patient) and/or treatment (inappropriate, delay or failure to treat). Major blood loss, pre-eclampsia and sepsis were the commonest clinical conditions where the severity of morbidity was deemed potentially preventable [14].

The UK implemented national reviews of SMM cases by adding it to their longstanding Confidential Enquiry into Maternal Deaths program [39]. Nominated reporting clinicians complete a monthly survey that is entered into a dedicated data collection system. The project does not provide population-level surveillance for a standarized definition of SMM; instead, it focuses on a changing set of severe morbidity/near miss conditions such as uterine rupture, eclampsia and pulmonary embolism to answer specific clinical questions [39]. Anonymous cases are reviewed by multidisciplinary experts to identify public health, hospital, and system problems that can inform future improvements in care [39].

Similarly, the Scottish Confidential Audit of Severe Maternal Morbidity (SCASMM) implemented a national 10 year surveillance project from 2003 to 2012 [40, 41]. All cases meeting one or more of the 14 SMM definitions were reported to the SCASMM during that time; cases of major obstetric hemorrhage (MOH) and eclampsia were reviewed in detail. Over the course of the project, the proportion of women with MOH who received appropriate care rose from 60% in 2004 to 80% in 2011 [41]. They found that the outcome could have been more favorable in just 4 to 10% of hemorrhage cases. Among 108 eclampsia cases that were assessed during the project period, 7 (6.5%) were deemed to have received suboptimal care [41].

The Netherlands also introduced SMM case reviews (67 cases) between 2005 and 2008 [42]. Cases were defined by ICU admission, uterine rupture, eclampsia/HELLP syndrome, massive obstetric hemorrhage, and cases referred to the panel by the treating obstetrician despite not being any of the specific criteria. Panel members were multidisciplinary and included members of the national maternal mortality review committee and clinicians of all obstetric disciplines. Substandard care and other potentially preventable factors were identified in 53 (74.6%) cases. The majority of factors identified (76.3%) were provider-related, 17.7% were health care system-related, and 6.0% were patient-related. The most common preventable factors were delays in diagnosis and treatment.

Since the WHO recommended that HICs with low maternal mortality ratios should begin to examine SMM to identify systems failures and intervention priorities [9], researchers in many HICs have turned their attention to SMM. Where surveillance has been conducted, the most common etiologies of SMM have been major obstetric hemorrhage and hypertensive disorders [13, 16, 37, 43–45]. Fewer countries have undertaken review of SMM to identify preventable factors and opportunities for improvements in maternity care provided by hospitals and health systems. Of those that have conducted SMM reviews, the most common preventable factors were provider-related, specifically failure to identify that the woman was progressing in severity, delays in diagnosis, and delays in treatment [14, 42, 46, 47].

Severe maternal morbidity in low and middle income countries

There has also been an increased interest in SMM in low and middle income countries (LMIC) in recent years, with studies in Sub-Saharan Africa (Table 2), Middle East (Table 3), Asia (Table 4) and Latin America (Table 5) estimating their SMM burden.

There is no standardized SMM definition; at least seven different definitions are used in LMICs as well as several individual studies that used their own definition. Of these, the World Health Organization’s (WHO) definition is the most commonly used. The WHO defines SMM as “a woman who nearly died but survived a complication that occurred during pregnancy, birth or within 42 days of termination of pregnancy” [48]. The WHO prefers to use the term “maternal near miss” to describe these women. A maternal near miss is identified when a woman develops one or more signs of organ dysfunction as described by 25 clinical, laboratory, or management criteria [48]. However, the applicability of the WHO criteria to low resource settings where certain laboratory and management tests/procedures are not routinely available is disputed and many countries must modify the WHO criteria for their settings [49–51]. For example, a study in Ethiopia modified the definition of SMM to include any woman who received 1 or more units of blood instead of 5 or more units of blood as the WHO suggests [51, 52]. The Global Network also modified the WHO definition by adding transfusion of any volume and excluding all WHO laboratory criteria for their definition of SMM [51]. The other definitions utilized in LMICs, such as Geller et al. [33] and Filippi
| Article          | Country                  | Setting                                                                 | Definition of SMM                                      | Estimated Prevalence | Leading Causes                                                                 |
|------------------|--------------------------|-------------------------------------------------------------------------|-------------------------------------------------------|----------------------|--------------------------------------------------------------------------------|
| Adeoye 2013 [66] | Nigeria                  | 1 tertiary referral hospital, Ille-Ife                                   | Filippi et al. 2005                                   | 109.9b              | Hemorrhage, hypertensive disorders, dystocia                                   |
| Ali 2011 [77]    | Sudan                    | 1 tertiary referral hospital, Kalassa                                    | Filippi et al. 2005                                   | 22.1                | Hemorrhage, infection, hypertensive disorders                                   |
| David 2014 [78]  | Mozambique               | 5 health facilities, Maputo city/province                              | eclampsia, infection hypertension, anemia, dystocia   | 20.2                | Hemorrhage, hypertensive disorders, infection                                   |
| Gebrewot 2014 [59]| Ethiopia                 | 10 public hospitals                                                     | hypertensive disorders, obstetric hemorrhage, dystocia| 90.8                | Dystocia or uterine rupture, hypertensive disorders, hemorrhage                |
| Goldenberg 2017  | Democratic Republic of Congo| 14 health centers and 3 hospitals, Equateur province                   | Modified WHO                                          | 37.3b               | Not reported by country                                                        |
| Goldenberg 2017  | Kenya                    | 23 health facilities and 3 referral hospitals, Busia, Bungoma and Kakamega counties | Modified WHO                                          | 31.2b               | Not reported by country                                                        |
| Goldenberg 2017  | Zambia                   | 8 health posts, 3 district hospitals and 1 referral hospital, Kafue and Chongwe districts | Modified WHO                                          | 13.0b               | Not reported by country                                                        |
| Herklots 2017 [79]| Tanzania                | Tertiary referral hospital, Zanzibar                                    | WHO                                                   | 9.0                 | Hemorrhage, hypertensive disorders                                              |
| Kalisa 2016 [80] | Rwanda                   | Provincial referral hospital, Musanze district                          | Modified WHO                                          | 21.5                | Hemorrhage, hypertensive disorders                                              |
| Kiruwa 2017 [81] | Somaliland               | Main referral hospital                                                  | WHO                                                   | 88.6                | Hemorrhage, hypertensive disorders                                              |
| Litorp 2014 [82] | Tanzania                 | 2 hospitals, Dar es Salaam                                             | WHO                                                   | 36                  | Hypertensive disorders, infection, hemorrhage                                   |
| Liyew 2017 [83]  | Ethiopia                 | 5 public hospitals, Addis Ababa                                        | WHO                                                   | 8.1                 | Hypertensive disorders, hemorrhage, abortive outcome                           |
| Lori 2012 [62]   | Liberia                  | Rural county                                                            | Modified WHO and Filippi et al. 2005                  | 16% of deliveries   | Hemorrhage, anemia, sepsis                                                     |
| Mbachu 2017 [54] | Nigeria                  | Private hospital, Elele                                                  | WHO                                                   | 198                 | Hemorrhage, abortive outcome, hypertensive disorders                           |
| Mekango 2017 [84] | Ethiopia                 | 6 public hospitals, Tigray                                              | Filippi et al. 2005                                   | 101                 | Hemorrhage, hypertensive disorders, dystocia                                   |
| Nakimuli 2016 [85] | Uganda                  | 2 referral hospitals, Central Uganda                                    | WHO                                                   | 8.42                | Hypertensive disorders, hemorrhage                                              |
| Nelissen 2013 [86] | Tanzania                | Referral hospital, rural                                                | Modified WHO                                          | 23.6                | Hemorrhage, abortive outcome, dystocia                                          |
| Oladapo 2016 [57] | Nigeria                  | 42 public tertiary hospitals                                            | WHO                                                   | 15.8                | Hemorrhage, hypertensive disorders                                              |

Note: SMM = Severe Maternal Morbidity; WHO = World Health Organization.
et al. [53] are much simpler than the WHO criteria and generally use clinical or management criteria, such as diagnosis of eclampsia or emergency hysterectomy to identify SMM.

It is difficult to compare SMM across countries due to the heterogeneity of SMM definitions. However, it is clear that the highest burden of SMM is in Sub-Saharan Africa, where estimates of SMM are as high as 198 per 1000 live births [54]. Asia also has a high SMM burden, with one study in India reporting a SMM rate of 120 per 1000 live births [55]. Hemorrhage and hypertensive disorders are the leading conditions contributing to SMM across all regions. These trends mirror maternal mortality trends, underscoring the importance of studying SMM.

Given the burden of collecting data on maternal deaths and reviewing these cases for potential preventability, there are large regions of the world such as Central Asia or Central Africa where there are no SMM estimates and we were not able to find any LMICs conducting national surveillance of SMM. However, Brazil is progressing towards a national surveillance system with the Brazilian Network for Surveillance of Severe Maternal Morbidity, which identifies SMM cases in 27 hospitals throughout the country [56]. Additionally, the Global Network Near-Miss Mortality System is conducting population-based surveillance of SMM at seven district/province level sites in Africa, Asia and Central America [51]. The majority of SMM studies that do take place occur in a single hospital, a single city or a single province/state and only rarely include multiple regions [57–60] This leads to vast differences in reported SMM rates between studies in the same country, such as the rate of SMM ranging from 9.6 to 120 per 1000 live births in two studies from India [55, 60].

The few studies of SMM case reviews that have been reported in LMICs include Ethiopia, Liberia, India and Moldova [59–62]. Overall, these studies incorporated a range of disease-specific, and pregnancy-specific clinical criteria to identify cases of SMM. India and Ethiopia found similar factors that contributed to SMM, such as lack of prenatal care, inability to access services, delays in seeking care, lack of medical equipment/supplies and health

| Article               | Country     | Setting                                | Definition of SMM | Estimated Prevalence a | Leading Causes                        |
|----------------------|-------------|----------------------------------------|-------------------|------------------------|---------------------------------------|
| Akrawi 2017 [91]     | Iraq        | Public tertiary hospital, Erbil City   | Modified WHO      | 8                      | Hypertensive disorders, hemorrhage    |
| Assarag 2015 [92]    | Morocco     | 3 public referral hospital, Marrakech | Sahel et al. 2011 | 12                     | Hemorrhage                            |
| Bashour 2015 [93]    | Egypt       | Public tertiary hospital, Cairo        | WHO                | 12.1                   | Hemorrhage                            |
| Bashour 2015         | Lebanon     | Public hospital, Beirut                | WHO                | 4.3                    | Hemorrhage                            |
| Bashour 2015         | Palestine   | Public referral hospital, Ramallah     | WHO                | 12.9                   | Hemorrhage                            |
| Bashour 2015         | Syria       | University hospital, Damascus          | WHO                | 4.5                    | Hemorrhage                            |
| Ghardallou 2016      | Tunisia      | Public tertiary hospital, Sousse       | WHO                | 5.86                   | Hemorrhage, hypertensive disorders    |
| Ghaizvavili 2016     | Iran        | 13 public and private hospital, Alborz province | WHO | 4.97 | Hypertensive disorders, hemorrhage |
| Jabir 2013 [63]      | Iraq        | 6 public hospital, Baghdad             | WHO                | 5.06                   | Hemorrhage, hypertensive disorders    |

*per 1000 live births
| Article      | Country         | Setting                                                                 | Definition of SMM                               | Estimated Prevalence | Leading Causes                     |
|-------------|-----------------|-------------------------------------------------------------------------|-----------------------------------------------|----------------------|-------------------------------------|
| Bolnga 2017 | Papua New Guinea | Provincial hospital, Madang Province                                    | Modified WHO                                  | 25.4                 | Hemorrhage                          |
| Goldenberg 2017 | India           | 18 primary health centers, 3 tertiary hospitals and 8 secondary hospitals Belagavi | Modified WHO                                  | 28.1^b               | Not reported by country             |
| Goldenberg 2017 | India           | 20 primary health centers, 10 tertiary hospitals and 129 secondary hospitals, Nappur | Modified WHO                                  | 4.4^b                | Not reported by country             |
| Goldenberg 2017 | Pakistan        | 47 primary health clinics, 25 secondary care facilities and 3 referral hospitals, Thatta district | Modified WHO                                  | 81.9^b               | Not reported by country             |
| Kalra 2014   | India           | Tertiary hospital, Rajasthan                                            | Geller et al. 2004                            | 4.8                  | Hemorrhage, hypertensive disorders  |
| Khan 2017    | India           | Tertiary referral hospital, New Delhi                                   | Geller et al. 2004, Pattinson et al. 2003, ICD-10 | 14                   | Hemorrhage, hypertensive disorders, anemia |
| Luexay 2014  | Laos            | Community survey, Sayaboury province                                    | WHO                                            | 9.8                  | Hemorrhage, hypertensive disorders  |
| Mazhar 2015  | Pakistan        | 16 government hospitals                                                 | WHO                                            | 7.0                  | Hemorrhage, hypertensive disorders, uterine rupture |
| Norhayati 2016 | Malaysia        | 2 tertiary hospitals, Kelantan                                          | WHO                                            | 2.2                  | Hemorrhage, hypertensive disorders  |
| Roopa 2013   | India           | Tertiary referral hospital, Manipal                                      | WHO                                            | 17.8                 | Hemorrhage, hypertensive disorders, sepsis |
| Pandey 2014  | India           | Medical college hospital, Uttar Pradesh                                 | WHO                                            | 120                  | Hemorrhage, hypertensive disorders, anemia |
| Purandare 2014 | India          | 6 medical college hospitals                                             | Pregnancy-specific disorders, Pre-existing disorders aggravated during pregnancy, Pregnancy-specific medical disorders, Incidental and accidental causes that occurred in pregnancy | 9.6                  | Hemorrhage                          |
| Rana 2013    | Nepal           | 9 tertiary hospitals, Kathmandu                                         | WHO                                            | 3.8                  | Hemorrhage, hypertensive disorders  |
| Shen 2013    | China           | Private tertiary hospital, Suzhou                                       | WHO                                            | 4                    | Hemorrhage, hypertensive disorders  |
| Shrestha 2010 | Nepal           | Tertiary hospital, Kathmandu                                            | Geller et al. 2004                             | 23.1^b               | Hemorrhage, hypertensive disorders  |
| Siddiqui 2012 | Pakistan        | Public tertiary hospital, Karachi                                       | Modified Waterstone et al. 2001               | 77                   | Hemorrhage, hypertensive disorders, uterine rupture |
| Tan 2015     | China           | 8 hospital, Sichuan province                                            | Hemorrhage, hypertensive disorders, uterine rupture, interventional radiology, blood transfusions, | 43.4                 | Did not report                      |
personnel issues [59, 60]. Liberia’s analysis focused only on understanding delays in seeking and receiving care [62]. Ethiopia, India and Moldova found that the review process is feasible and that providers were more accepting of SMM reviews compared to mortality reviews because they felt the process did not assign blame and they could highlight instances where they had provided excellent care and saved the woman’s life [59–61].

Globally, the pattern is emerging that substandard maternal health care and suboptimal use of evidence-based strategies to prevent and treat morbidity are common across many countries regardless of wealth, contributing to the high burden of SMM [52, 58, 63, 64]. Preventability reviews of SMM have the potential to dramatically improve maternal health but few LMICs have conducted SMM reviews and they did not utilize a preventability framework. The lack of surveillance and review in countries with the highest burden of SMM and maternal death only perpetuates the poor maternal health outcomes observed in these regions. Currently, the state of SMM surveillance reflects the broad disinvestment in maternal health, as a standardized definition that is globally applicable is elusive and large regions of world have no SMM estimates.

### Effects of SMM on delivery outcomes and infants

Severe maternal morbidity not only puts the woman’s life at risk, her fetus/neonate may suffer consequences of morbidity and mortality as well. Preventing a woman’s progression along the continuum of severity may also improve delivery outcomes and newborn health. If we incorporate delivery outcomes, the expanded continuum

### Table 4: Estimates of the Prevalence of Severe Maternal Morbidity in Asia (Continued)

| Article          | Country                | Setting                                      | Definition of SMM                                      | Estimated Prevalence | Leading Causes                     |
|------------------|------------------------|----------------------------------------------|--------------------------------------------------------|----------------------|------------------------------------|
| Tanimia 2016     | Papua New Guinea       | National referral hospital, Port Moresby     | Modified WHO                                           | 9.1                  | Hemorrhage, hypertensive disorders, infection |

* per 1000 live births

* per 1000 deliveries

### Table 5: Estimates of the Prevalence of Severe Maternal Morbidity in Latin America

| Article          | Country                | Setting                                      | Definition of SMM                                      | Estimated Prevalence | Leading Causes                     |
|------------------|------------------------|----------------------------------------------|--------------------------------------------------------|----------------------|------------------------------------|
| De Mucio 2016    | Argentina              | 3 hospitals                                  | WHO                                                     | 2.62                 | Not reported                       |
| De Mucio 2016    | Colombia               | 1 hospital                                   | WHO                                                     | 8.98                 | Not reported                       |
| De Mucio 2016    | Dominican Republic     | 1 hospital                                   | WHO                                                     | 22.56                | Not reported                       |
| De Mucio 2016    | Ecuador                | 1 hospital                                   | WHO                                                     | 8.77                 | Not reported                       |
| De Mucio 2016    | Honduras               | 2 hospitals                                  | WHO                                                     | 16.31                | Not reported                       |
| De Mucio 2016    | Nicaragua              | 1 hospital                                   | WHO                                                     | 8.39                 | Not reported                       |
| De Mucio 2016    | Paraguay               | 1 hospital                                   | WHO                                                     | 5.99                 | Not reported                       |
| De Mucio 2016    | Peru                   | 1 hospital                                   | WHO                                                     | 34.92                | Not reported                       |
| Dias 2014        | Brazil                 | Birth in Brazil national survey              | WHO                                                     | 10.21                | Not reported                       |
| Goldenberg 2017  | Guatemala              | 1 referral hospital, 30 health centers, and 42 health posts, Chimaltenango region | Modified WHO | 61.1*b                         | Not reported by country          |
| Karolinski 2013  | Argentina              | 25 public hospitals                          | ICU admit, hysterectomy, organ dysfunction             | 8.49                 | Not reported                       |
| Lima 2016        | Brazil                 | Tertiary hospital                            | WHO                                                     | 10.8                 | Not reported                       |
| Madeiro 2015     | Brazil                 | Tertiary hospital, Piaui                      | WHO                                                     | 9.6                  | Hypertensive disorders, hemorrhage, infection |
| Galveo 2014      | Brazil                 | 2 referral hospitals, Sergipe                | WHO                                                     | 5.8                  | Hypertensive disorders, hemorrhage |

* per 1000 live births

* per 1000 deliveries
includes both mother and child: normal/healthy pregnancy - > morbidity - > severe morbidity - > death - > delivery outcome - > neonatal morbidity.

Adverse delivery outcomes such as fetal death, NICU admission, preterm birth, 5-min Apgar score less than 7 and low birth weight occur at a higher frequency among women with SMM (Table 6). A nationwide study in New Zealand found that 49.4% of women with SMM suffered one or more of these adverse delivery outcomes. Preterm birth is significantly associated with SMM, with between 22 and 41% of women with SMM having a preterm birth [65, 66]. Interestingly, HICs and LMICs report similar rates of preterm birth among women with SMM. Neonatal intensive care unit (NICU) admission rates are also high among women with SMM. These rates are higher in high and middle-income countries, which likely reflect the lack of availability of NICUs in low-income countries. SMM significantly increases the odds of a fetal death in both HICs and LMICs [65, 67]. Many of these adverse delivery outcomes are associated with the woman having preeclampsia and a need for delivery as her disease process progresses [43, 68].

Adverse delivery outcomes are often preventable. New Zealand found that 38.8% of adverse delivery outcomes for women with SMM were preventable and suggested that better care of the woman while pregnant or during delivery could have improved the outcome. Provider (delay in timely diagnosis and treatment) and system (poor communication, failure to follow evidence-based guidelines) factors were the major preventable issues. In Scotland, audits of SMM cases were credited with the steep decline of perinatal mortality observed in Scotland.

### Table 6: Adverse Delivery Outcomes among Women with SMM

| Author                  | City/State, Country | SMM Definition                                                                 | Adverse Delivery outcome | Estimated Prevalence |
|-------------------------|---------------------|--------------------------------------------------------------------------------|--------------------------|----------------------|
| Adeoye 2013 [66]        | Ile-Ife, Nigeria    | Filippi et al. 2005                                                            | Fetal death              | 28.4                 |
|                         |                     |                                                                                 | Low birth weight         | 44.4                 |
|                         |                     |                                                                                 | Preterm<sup>c</sup>      | 41.3                 |
| Koch [38]               | Illinois, United States | ICU admission, ≥4 units packed red blood cells                | Fetal death              | 8.9                  |
|                         |                     |                                                                                 | NICU                     | 39.7                 |
|                         |                     |                                                                                 | Apgar < 7                | 16.9                 |
|                         |                     |                                                                                 | Low birth weight         | 31.2                 |
|                         |                     |                                                                                 | Preterm                  | 38.1                 |
| Lawton 2017 [personal communication] | New Zealand | ICU/HDU admission                                                                  | Fetal death              | 5.1                  |
|                         |                     |                                                                                 | NICU                     | 44.1                 |
|                         |                     |                                                                                 | Preterm                  | 38.5                 |
| Jakobsson 2015 [65]     | Finland             | abnormally invasive placenta, uterine rupture, emergency peripartum hysterectomy | Fetal death              | 7.5                  |
|                         |                     |                                                                                 | NICU                     | 31.2                 |
|                         |                     |                                                                                 | Apgar < 7                | 19                   |
|                         |                     |                                                                                 | Low birth weight         | 16.1                 |
|                         |                     |                                                                                 | Preterm                  | 22.3                 |
| Nakimuli 2015 [85]      | Kampala, Uganda     | WHO                                                                              | Fetal death              | 12.0                 |
|                         |                     |                                                                                 | NICU                     | 18.4                 |
|                         |                     |                                                                                 | Low birth weight         | 15.8                 |
| Nardello 2017 [68]      | Aracaju, Brazil     | WHO                                                                              | Fetal death              | 8.9                  |
|                         |                     |                                                                                 | NICU                     | 41.8                 |
|                         |                     |                                                                                 | Apgar < 7                | 12.5                 |
|                         |                     |                                                                                 | Low birth weight         | 36.7                 |
|                         |                     |                                                                                 | Preterm                  | 38                   |
| Oliveira 2013 [114]     | Recife, Brazil      | WHO                                                                              | Fetal death              | 19.5                 |
|                         |                     |                                                                                 | Apgar < 7                | 9.0                  |

<sup>a</sup>Adverse delivery outcomes are defined as:
- 5 min Apgar score < 7
- birthweight less than 2500 g
- < 37 weeks gestational age

<sup>b</sup>percent of SMM cases with adverse delivery outcome
<sup>c</sup> < 38 weeks gestational age at delivery
between 2005 and 2012 [40]. In the UK, reviews of stillbirth and neonatal death found that nearly 80% of those deaths could have been prevented by improvements in care [69]. These findings raise the important point that reducing preventable severe maternal morbidity not only reduces the potential for maternal mortality but also improves the health and well-being of the newborn.

A call to action
Despite gains throughout the 20th century, maternal health remains a major public health concern. It is therefore critical to implement the global study of SMM through enhanced surveillance and case review to lay the foundational work to develop initiatives for quality care improvement efforts and the ability to translate these findings into policy and practice to improve the health of women and their infants. The observed increase in maternal morbidity and mortality is not only a failure to achieve broad public health goals of improved women’s health, but also contribute to sub-optimal delivery outcomes and poor infant health.

HICS generally have the resources to implement surveillance and reviews of SMM cases. This can be implemented as hospital level quality improvement initiatives or at a regional or statewide level. There are several well validated tools [33, 36] that can be utilized to identify women with severe morbidity as well as tools to conduct multidisciplinary reviews. LMICs may want to begin with surveillance efforts using a limited number of variables to estimate the significance of the issue and incorporate SMM reviews into ongoing maternal mortality reviews.

Conclusion
Despite gains throughout the 20th century, maternal health remains a major global public health concern. Of particular concern is that SMM rates appear to be trending upward [11, 70]. Such increases in maternal morbidity not only are failures to achieve broad public health goals of improved women’s health, but also contribute to sub-optimal delivery outcomes and poor infant health. Therefore, it is incumbent upon all countries to implement surveillance initiatives to understand the burden of severe morbidity and to implement review processes for assessing potential preventability. Preventing a woman’s progression along the continuum of severity may also improve delivery outcomes and newborn health. This will enable us to gather the data necessary to implement evidence-based interventions that will lead to lower rates of SMM and, ultimately, maternal mortality (MDG 5) and subsequently lower rates of perinatal births and neonatal deaths (MDG 4).

Availability of data and materials
Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

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