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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.

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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 incomes 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 times 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

Table 1 Estimates of the Prevalence of Severe Maternal Morbidity in High-Income Countries

Author (Year)	Country	Definition of SMM	Estimated Prevalence ^a	Leading Causes
Bouvier-Colle (2012) [13]	17 EU Countries	Eclampsia	0.2–1.6	
	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	
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	
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	Major obstetric hemorrhage, ICU/coronary care admission
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	

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

Author (Year)	Country	Definition of SMM	Estimated Prevalence ^a	Leading Causes
O'Malley (2016) [75]	Ireland	Assisted ventilation including tracheostomy	0.15	
		Curettage with general anesthesia	0.01	
		Dialysis	0.01	
		Evacuation of hematoma	0.50	
		Hysterectomy	0.24	
		Procedures to reduce blood flow to uterus	0.06	
		Re-closure of disrupted cesarean section wound	0.31	
		Repair of bladder or cystostomy	0.31	
		Repair of intestine	0.008	
		WHO criteria	3.6	Hemorrhage
Ozimek (2016) [37]	United States	Scottish Audit of SMM criteria	18.4	Hypertension
		"Gold standard" clinical guidelines from Main (2016)	9.2	Hemorrhage, preeclampsia/eclampsia
Zanconato (2012) [44]	Italy	ICU admission, transfusion ≥ 4 units, emergency peripartum hysterectomy, arterial embolization	8.5	Hypertensive disorders, hemorrhage, sepsis
Zwart (2010) [76]	The Netherlands	ICU admission, eclampsia/HELLP syndrome, uterine rupture, major hemorrhage, miscellaneous	7.1 overall 6.3 Western ethn 8.4 non-Western ethn	
		Peripartum hysterectomy	3.5	
		Abnormally invasive placenta	4.6	
		Severe hemorrhage at delivery	11.6	

^aPer 1000 live births

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].

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 standardized 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

Table 2 Estimates of the Prevalence of Severe Maternal Morbidity in Sub-Saharan Africa

Article	Country	Setting	Definition of SMM	Estimated Prevalence ^a	Leading Causes
Adeoye 2013 [66]	Nigeria	1 tertiary referral hospital, Ile-Ife	Filippi et al. 2005	109.9 ^b	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
Gebrehiwot 2014 [59]	Ethiopia	10 public hospitals	hypertensive disorders, obstetric hemorrhage, dystocia, infection, anemia	90.8	Dystocia or uterine rupture, hypertensive disorders, hemorrhage
Goldenberg 2017 [51]	Democratic Republic of Congo	14 health centers and 3 hospitals, Equateur province	Modified WHO	37.3 ^b	Not reported by country
Goldenberg 2017	Kenya	23 health facilities and 3 referral hospitals, Busia, Bungoma and Kakamega counties	Modified WHO	31.2 ^b	Not reported by country
Goldenberg 2017	Zambia	8 health posts, 3 district hospitals and 1 referral hospital, Kafue and Chongwe districts	Modified WHO	13.0 ^b	Not reported by country
Herklotz 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
Kiruja 2017 [81]	Somaliland	Main referral hospital	WHO	88.6	Hemorrhage, hypertensive disorders, infection
Litorp 2014 [82]	Tanzania	2 hospitals, Dar es Salaam	WHO	36	Hypertensive disorders, 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, abortive outcome

Table 2 Estimates of the Prevalence of Severe Maternal Morbidity in Sub-Saharan Africa (Continued)

Article	Country	Setting	Definition of SMM	Estimated Prevalence ^a	Leading Causes
Rulisa 2015 [87]	Rwanda	University hospital, Kigali	WHO	8	Sepsis, hypertensive disorders, hemorrhage
Sayinzoga 2017 [88]	Rwanda	4 rural district hospitals	Modified WHO	36	Hemorrhage, uterine rupture, abortive outcome
Soma-Pillay 2015 [89]	South Africa	9 delivery facilities, Gauteng province	WHO	4.4 ^c	Hemorrhage, hypertensive disorders, sepsis
Tuncalp 2013 [90]	Ghana	Tertiary referral hospital, Accra	WHO	28.6	Not reported

^aper 1000 live births^bper 1000 deliveries^cper 1000 pregnancies

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

Table 3 Estimates of the Prevalence of Severe Maternal Morbidity in North Africa and Middle East

Article	Country	Setting	Definition of SMM	Estimated Prevalence ^a	Leading Causes
Akrawi 2017 [91]	Iraq	Public tertiary hospital, Erbil City	Modified WHO	8.2	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 [94]	Tunisia	Public tertiary hospital, Sousse	WHO	5.86	Hemorrhage, hypertensive disorders
Ghazivakili 2016 [95]	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

^aper 1000 live births

Table 4 Estimates of the Prevalence of Severe Maternal Morbidity in Asia

Article	Country	Setting	Definition of SMM	Estimated Prevalence ^a	Leading Causes
Bolunga 2017 [96]	Papua New Guinea	Provincial hospital, Madang Province	Modified WHO	25.4	Hemorrhage
Goldenberg 2017 [51]	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, Nagpur	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 [97]	India	Tertiary hospital, Rajasthan	Geller et al. 2004	4.8	Hemorrhage, hypertensive disorders
Khan 2017 [98]	India	Tertiary referral hospital, New Delhi	Geller et al. 2004, Pattinson et al. 2003, ICD-10	14	Hemorrhage, hypertensive disorders, anemia
Luexay 2014 [99]	Laos	Community survey, Sayaboury province	WHO	9.8	Hemorrhage, hypertensive disorders
Mazhar 2015 [100]	Pakistan	16 government hospitals	WHO	7.0	Hemorrhage, hypertensive disorders, uterine rupture
Norhayati 2016 [101]	Malaysia	2 tertiary hospitals, Kelantan	WHO	2.2	Hemorrhage, hypertensive disorders
Roopa 2013 [102]	India	Tertiary referral hospital, Manipal	WHO	17.8	Hemorrhage, hypertensive disorders, sepsis
Pandey 2014 [55]	India	Medical college hospital, Uttar Pradesh	WHO	120	Hemorrhage, hypertensive disorders, anemia
Purandare 2014 [60]	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 [103]	Nepal	9 tertiary hospitals, Kathmandu	WHO	3.8	Hemorrhage, hypertensive disorders
Shen 2013 [104]	China	Private tertiary hospital, Suzhou	WHO	4	Hemorrhage, hypertensive disorders
Shrestha 2010 [105]	Nepal	Tertiary hospital, Kathmandu	Geller et al. 2004	23.1 ^b	Hemorrhage, hypertensive disorders
Siddiqui 2012 [106]	Pakistan	Public tertiary hospital, Karachi	Modified Waterstone et al. 2001	77	Hemorrhage, hypertensive disorders, uterine rupture
Tan 2015 [107]	China	8 hospital, Sichuan province	Hemorrhage, hypertensive disorders, uterine rupture, interventional radiology, blood transfusions,	43.4	Did not report

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

Article	Country	Setting	Definition of SMM	Estimated Prevalence ^a	Leading Causes
Tanimia 2016 [108]	Papua New Guinea	National referral hospital, Port Moresby	laparotomy, ICU admission, multiple organ dysfunction syndromes	Modified WHO 9.1	Hemorrhage, hypertensive disorders, infection

^aper 1000 live births^bper 1000 deliveries

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 5 Estimates of the Prevalence of Severe Maternal Morbidity in Latin America

Article	Country	Setting	Definition of SMM	Estimated Prevalence ^a	Leading Causes
De Mucio 2016 [109]	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 [110]	Brazil	Birth in Brazil national survey	WHO	10.21	Not reported
Goldenberg 2017 [51]	Guatemala	1 referral hospital, 30 health centers, and 42 health posts, Chimaltenango region	Modified WHO	61.1 ^b	Not reported by country
Karolinski 2013 [58]	Argentina	25 public hospitals	ICU admit, hysterectomy, organ dysfunction	8.49	Not reported
Lima 2016 [111]	Brazil	Tertiary hospital	WHO	10.8	Not reported
Madeiro 2015 [112]	Brazil	Tertiary hospital, Piaui	WHO	9.6	Hypertensive disorders, hemorrhage, infection
Galveo 2014 [113]	Brazil	2 referral hospitals, Sergipe	WHO	5.8	Hypertensive disorders, hemorrhage

^aper 1000 live births^bper 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 ^a	Estimated Prevalence ^b
Adeoye 2013 [66]	Ile-Ife, Nigeria	Filippi et al. 2005	Fetal death	28.4
			Low birth weight	44.4
			Preterm ^c	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
			Fetal death	5.1
Lawton 2017 [personal communication]	New Zealand	ICU/HDU admission	NICU	44.1
			Preterm	38.5
			Fetal death	7.5
			NICU	31.2
Jakobsson 2015 [65]	Finland	abnormally invasive placenta, uterine rupture, emergency peripartum hysterectomy	Apgar < 7	19
			Low birth weight	16.1
			Preterm	22.3
			Fetal death	12.0
			NICU	18.4
Nakimuli 2015 [85]	Kampala, Uganda	WHO	Low birth weight	15.8
			Fetal death	8.9
			NICU	41.8
			Preterm	38
Nardello 2017 [68]	Aracaju, Brazil	WHO	Apgar < 7	12.5
			Low birth weight	36.7
			Preterm	38
			Fetal death	19.5
Oliveira 2013 [114]	Recife, Brazil	WHO	Apgar < 7	9.0

^aAdverse delivery outcomes are defined as:

- 5 min Apgar score < 7
- birthweight less than 2500 g
- < 37 weeks gestational age

^bpercent of SMM cases with adverse delivery outcome

^c< 38 weeks gestational age at delivery

between 2005 and 2012 [40]. In the UK, reviews of still-birth 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 preterm births and neonatal deaths (MDG 4).

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SEG conceptualized the study; ARK and CEG reviewed published literature; SEG, ARK, CEG, EJM, FS, BL drafted and revised the manuscript. All authors have read and approved the final manuscript.

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