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Global and regional estimates of maternal near miss: a systematic review, meta-analysis and experiences with application

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ABSTRACT

Introduction Maternal near miss (MNM) is a useful means to examine quality of obstetric care. Since the introduction of the WHO MNM criteria in 2011, it has been tested and validated, and is being used globally. We sought to systematically review all available studies using the WHO MNM criteria to develop global and regional estimates of MNM frequency and examine its application across settings.

Methods We conducted a systematic review by implementing a comprehensive literature search from 2011 to 2018 in six databases with no language restrictions. The predefined data collection tool included sections on study characteristics, frequency of near-miss cases and study quality. Meta-analysis was performed by regional groupings. Reported adaptations, modifications and remarks about application were extracted.

Results 7292 articles were screened by title and abstract, and 264 articles were retrieved for full text review for the meta-analysis. An additional 230 articles were screened for experiences with application of the WHO MNM criteria. Sixty studies with near-miss data from 56 countries were included in the meta-analysis. The pooled global near-miss estimate was 1.4% (95% CI 0.4% to 2.5%) with regional variation in MNM frequency. Of the 20 studies that made adaptations to the criteria, 19 were from low-resource settings where lab-based criteria were adapted due to resource limitations.

Conclusions The WHO MNM criteria have enabled the comparison of global and sub-national estimates of MNM frequency. There has been good uptake in low-resource countries but contextual adaptations are necessary.

WHAT IS ALREADY KNOWN?

⇒ In recent years, there has been growing interest in the application of the maternal nearmiss (MNM) concept as an adjunct to maternal mortality to improve quality of care.

⇒ -A previously conducted systematic review in 2012 on the prevalence of MNM found that there were variations in the criteria used to identify MNM cases and it was limited in its assessment of the WHO MNM criteria as it was newly introduced.

WHAT ARE THE NEW FINDINGS?

⇒ Using the WHO MNM criteria, the pooled global near-miss estimate was 1.4% (95% CI 0.4% to 2.5%) and there was no substantial between-study heterogeneity.

⇒ In low-resource countries, the WHO MNM criteria were modified and excluded a number of laboratory tests and interventions due to resource constraints.

⇒ The most commonly modified intervention was the threshold for blood transfusion.

WHAT DO THE NEW FINDINGS IMPLY?

⇒ The WHO MNM criteria have enabled standardised case identification and allowed for the comparison of global and subnational estimates of MNM frequency and inform quality improvement efforts.

⇒ There has been good uptake of the WHO MNM criteria in low-resource settings.

⇒ Due to resource constraints in low-resource settings, there might be a need for local adaptation, where appropriate.

BACKGROUND

During the last two decades, there has been a substantial and worldwide reduction of maternal mortality.[1] As maternal deaths have dropped significantly over the past two decades, measurement of maternal morbidity is crucial to the ongoing elaboration of the post-2015 Sustainable Development Goals (SDGs). Studying maternal near miss (MNM), women who nearly died but survived a complication during pregnancy, childbirth or post partum, is increasingly recognised as a useful means to examine quality of obstetric care.[2]

As the frequency of MNM cases at the facility level are generally higher than maternal deaths, a sufficient number of cases can generate consistent and actionable information to improve quality of care. MNM also allows to facilities to work on cases

with a survival outcome, enabling open discussions and reducing the fear of blame. However, routine implementation and wider application of the near-miss approach in reviewing clinical care has been limited due to the lack of a standard definition and uniform case-identification criteria. During the 1990s and early 2000s, there was a multitude of operational definitions of MNM that made it difficult to obtain overall estimates based on those definitions.

In 2009, a World Health Organization (WHO) technical working group was established, and published an identification criteria for near miss which aims to capture standardised data that allows for comparability of the quality of care between settings, geographical areas and across time.[3]

WHO has previously conducted two systematic reviews in 2004 and 2012 to report on the prevalence of near miss.[4 5] The previous systematic reviews included all available studies on near miss with an emphasis on the different definitions of near miss and the criteria for identification of the cases. The updated systematic review in 2012 found that there were variations in the criteria used to identify MNM cases especially in the literature published before 2011.[5] Since 2011, the WHO NM criteria have been tested and validated and therefore, the first objective of our study was to determine the global and regional frequency ofMNM using studies that employed the WHO MNM criteria. Our second objective was to examine adaptions and modifications of the WHO MNM criteria especially in resource- limited settings where the uptake of the WHO MNM criteria has been high[6] and the WHO has advocated for using context-relevant definitions in these settings.

METHODS

Systematic review and meta-analysis

Search strategy

We performed a literature search to identify peer-reviewed articles published between 1 January 2011 and 31 December 2018. The databases that were searched include: PubMed, Embase, Lilacs and Popline. We also searched the following Regional Indexes Medici, coordinated by each WHO Regional Office: African Index Medicus, Index Medicus for Eastern Mediterranean Region Western Pacific Region Index Medicus (Index Medicus for South-East Asia Region. Reference lists of the included articles were also reviewed in order to further identify eligible studies . The search strategy in table 1 reflects the main framework and key search terms. The main framework of the search strategy was adapted for each of the databases.

Table 1 Search strategy

1	**WHO near miss.mp.**
2	near miss.mp.
3	2 not 1
4	near miss*.mp.
5	exp Pregnancy Complications/
6	exp Pregnancy Outcome/
7	exp Maternal Mortality/
8	exp Maternal Health/
9	exp Maternal Health Services/
10	exp Postpartum Period/
11	exp Pregnancy/
12	exp Maternal Welfare/
13	(matern* or mother* or pregnan* or obstetric* or postpartum or post-partum).mp.
14	5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13

Selection criteria

Studies were eligible for inclusion for the meta-analysis if they: (1) contained near-miss incidence or prevalence data; (2) included data from 2011 onwards; (3) had a sample size of ≥200 subjects; (4) were published between 1 January 2011 and 31 December 2018; and (5) used the WHO MNM criteria. There were no language restrictions in place. All authors reviewed publications in English. Publications in Spanish and Portuguese were translated in full by JPS and CLTR.

Data extraction

The titles and abstracts of all identified citations for the meta-analysis were reviewed independently by at least two assessors (CLTR, JPS or OT). Three reviewers (TF, CL and CLTR) independently screened titles and abstracts of the studies for the narrative review. Full text copies of any studies that were considered to be potentially eligible for inclusion by at least one assessor were retrieved. The full text articles were assessed for inclusion independently by two reviewers (CLTR and JPS), and any discrepancies were resolved by discussion, or by consulting the third reviewer (OT) if consensus could not be reached. The reviewers were not blinded to the authorship or results of the included studies. Any discrepancies were again resolved by discussion, or by consulting the third reviewer.

Data were extracted from the full text articles independently by two reviewers (CLTR and JPS), using a predefined and piloted data collection form that was initially developed for the 2012 review, and updated accordingly for the current meta-analysis. Data were extracted on the general study characteristics (eg, study design, population, setting), and the prevalence/incidence of MNM and the definition/identification criteria used. The authors of the original studies were contacted if additional information or clarification was required. We adapted the National Institute of Health (NIH) Quality Assessment Tool Observational Cohort and Cross-Sectional Studies (https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools) for the purposes of this study and rated studies as good, fair or poor quality.

Data analysis

The characteristics of each study were described, along with the reported measures of MNM frequency. The incidence or prevalence measures were calculated by dividing the number of identified MNM cases by the number of deliveries or live births (whichever was reported in the study) that occurred during the study period. We aggregated MNM incidence and prevalence to determine frequency. NM frequency was reported as ranges and by SDG regional groupings (https://unstats.un.org/sdgs/report/2019/regional-groups/).

We performed a meta-analysis as we only included studies that applied the WHO MNM criteria, and therefore, would not have variable definitions of near miss. Estimates were reported as percentages with 95% CIs. Between study heterogeneity was assessed using the I^2 statistic. All of the analyses were performed using STATA V.16 (StataCorp).

Experiences with application of WHO NM criteria

We reviewed papers included in the meta-analysis to understand the experiences with application by examining adaptions or modifications that were made to the WHO MNM criteria. As we hypothesised that the WHO MNM criteria would be highly used in low-resource settings and possibly require contextual adaptations, we conducted an additional search to identify further papers from these settings. We defined low-resource settings as low-income and lower-middle-income countries as defined by the World Bank Country and Lending Groups (https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups). We searched the same databases as the meta-analysis and used the same search terms as the systematic review with the addition of 'low' and 'lower middle-income countries'. We handsearched references of pertinent papers to identify further eligible papers. A grey literature search using Google was also performed.

The methods section of each study was carefully reviewed to determine whether adaptations or modifications were made to one or more aspects of the WHO MNM criteria (severe maternal complications, critical interventions or intensive care unit (ICU) use and life-threatening conditions). The discussion section of studies was also reviewed for remarks on challenges to applying the WHO MNM criteria in the study setting. Data were extracted on general study characteristics (eg, study design, setting and country) and adaptations made to each aspect of the MNM criteria Relevant text on challenges to applicability were also extracted. The data are reported in a narrative fashion.

Patient and public involvement

As this is a systematic review, there was no patient or public involvement

RESULTS

A total of 7292 articles underwent initial screening by title and abstract, 264 had a full text evaluation, and a total of 60 studies met all of the criteria for inclusion for the meta-analysis (figure 1).[7–66] Four of these studies

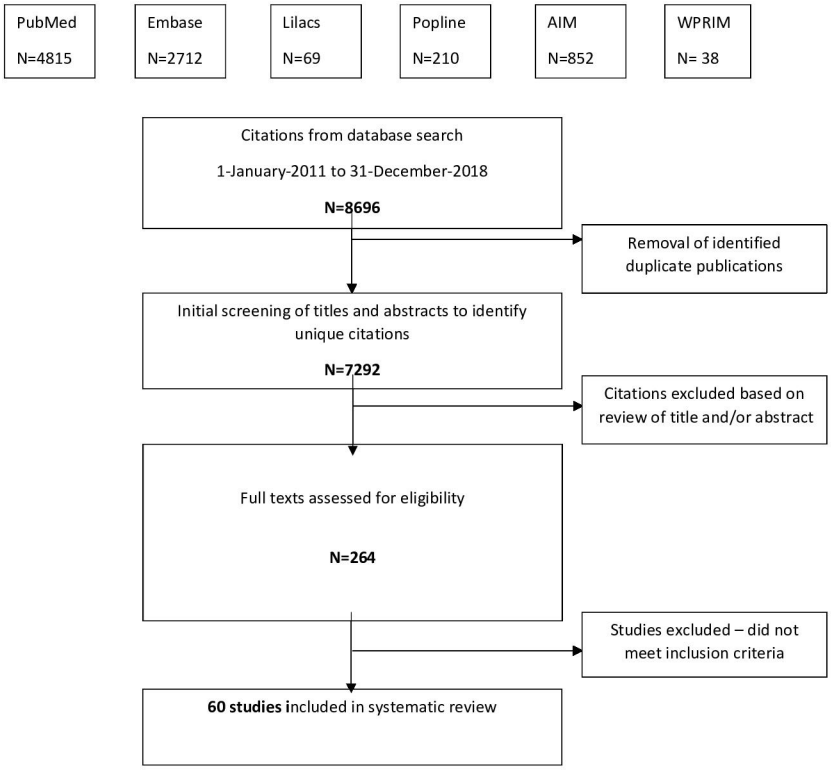

Figure 1 Review and selection of articles.

Table 2 Overview of near miss frequency and meta-analysis by region

Region	Near miss frequency (range) [N=60 studies]	Near miss meta-analysis ES [95% CI] [N= 57 studies]
Central and Southern Asia	1.67–120	0.022 [95% CI −0.012 to 0.055]
Eastern and South Eastern Asia	2.1–12.7	0.006 [95% CI −0.090 to 0.102]
Sub Saharan Africa	0.39–198.5	0.024 [95% CI −0.004 to 0.052]
Latin America and the Caribbean	2.2–77.2	0.011 [95% CI −0.001 to 0.023]
Northern Africa and Western Asia	3.1–12.9	0.007 [95% CI −0.087 to 0.100]
Oceania	4.8–25.4	0.016 [95% CI −0.093 to 0.126]
Europe and Northern America	47.9	0.048 [95% CI −0.031 to 0.127]

were multi-country studies.[18 27 39 55] The remaining 56 studies were from 24 countries, with 15 studies (27%) from Sub-Saharan Africa, 3 studies (5%) from Northern Africa and Western Asia, 15 studies (27%) from Central and Southern Asia, 3 studies (5%) from Eastern and South-Eastern Asia, 14 studies (25%) from Latin America and the Caribbean, 5 studies (9%) from Oceania and one study (2%) from Europe and Northern America. Only four studies were from high-income countries and 19 studies were from upper-middle-income countries. The majority were cross sectional studies (57%) and all studies used data from facilities, mainly tertiary care hospitals. Only 10 studies used deliveries as the denominator to report MNM rate while the other 50 studies used live births as the denominator. Study characteristics are detailed in online supplemental table S1. Seventy-three percent of the studies were rated as good quality, 25% were of fair quality and only one study (4%) was found to be of poor quality (online supplemental table S2).

Table 2 summarizes the MNM frequencies and meta-analysis results by region.

Near miss by SDG regional groupings

Online supplemental table 3 shows the near-miss ratios in each region. Sub-Saharan Africa had the largest variation, with the lower near-miss ratio being 0.39/1000 live births and the upper near-miss ratio being 198.5/ 1000 live births. Latin America and the Caribbean also had a variable range, 2.2–77. 2/1000 live births. In Central and Southern Asia, the near-miss ratio ranged from 1.67–120/ 1000 live births. NM ratios in Eastern and South-Eastern Asia (2.1–12.7/1000 live births) and Northern Africa and Western Asia (3.1–12.9/ 1000 live births) were similar. Studies from Oceania had a reported range of 4.8–25.4/ 1000 live births. There was only one study from Europe and Northern America, from the USA, which had a near-miss rate of 47.9/ 1000 live births.[7] This study specifically looked at a multi-ethnic population and sought to determine differences in near-miss rates between different ethnic groups.

Meta-analysis of near miss using WHO approach

Three studies were excluded from the meta-analysis. Using the same approach as the 2012 review, two studies were deemed to be outliers as the data points were out of range when compared with other regional data points.[25 63] One multicountry study was excluded because we could not determine the data for individual countries included in the study.[55]

The pooled near-miss estimate using the WHO criteria was 1.4% (95% CI 0.4% to 2.5%). Confidence intervals (CI) in the analysis were generally narrow (Online supplemental table S4a). Our data do not show substantial between-study heterogeneity (online supplemental table S4b).

Regional meta-analysis found a pooled near-miss estimate of 0.6% in Eastern and South-Eastern Asia, 0.7% in Northern Africa and Western Asia, 1.1% in Latin America and the Caribbean, 1.6% in Oceania, 2.2% in Central and Southern Asia, 2.4% in sub-Saharan Africa and 4.8% in Europe and Northern America.

Experiences of application of WHO NM criteria

In addition to reviewing each of the papers included in the meta-analysis, we screened an additional 230 articles for adaptations, modifications and remarks on application of the WHO NM criteria. A total of 20 studies from 14 countries met our inclusion criteria of modifying or adapting the WHO MNM criteria (online supplemental table S5).[13 17 23–25 30 43 44 49–52 54 60 64 67–71]

Fifteen studies from the meta-analysis included adaptations to the WHO MNM criteria.[13 17 23–25 30 43 44 49–52 54 60 64] Fourteen of these studies were from low-resource settings and only one study was from an upper-middle-income country.[17] The additional search yielded five more papers, all of which were from low-resource settings.[67–71]

Twelve of the included studies were from sub-Saharan Africa,[13 23 43 44 52 54 64 67–71] one study each from Northern Africa and Western Asia,[50] three studies from Central and Southern Asia,[16 25 30] two studies from Eastern and South-eastern Asia[17 24] and two studies from Oceania.[49 51] All were observational studies with one study being a population-based study[24] and another being a mixed-methods descriptive study.[16] Almost all were set in tertiary, teaching or referral hospitals. Five studies were set in district hospitals[16 49 51 68–70] including one study which was set in rural district hospitals.[69] Two studies adapted the WHO MNM criteria for use at the community level.[16 24]

At the level of tertiary or district hospitals, nine studies expanded the criteria for severe maternal complications to include conditions such as obstructed labour, uterine infection, complications of caesarean section and malaria.[23 43 50 54 60 64 67 68 71] Four studies included additional criteria for life threatening conditions.[30 44 50 68] Three of these studies included anaemia but with varying definitions.[30 50 68] The most commonly excluded laboratory

criteria due to unavailability were lactate (10 studies), pH (11 studies), arterial oxygen tension (pAO2)/fractional inspired oxygen (FiO2) (10 studies), urine ketoacids (6 studies), creatinine (3 studies), bilirubin (four studies) and platelets (1 study). Interventions excluded due to unavailability were dialysis (five studies) and continuous use of vasoactive drugs (six studies). The threshold for blood transfusion was modified in 63% of the studies (n=12).[13 23 44 49–51 64 67–71] One study included all types of blood products whereas one study modified it to ≥4 units, four studies modified it to ≥3 units and 3 studies each to ≥2 units and ≥1 unit, respectively.

The two studies that modified the WHO MNM criteria for use in the community applied them at community level birthing centres in Nepal[16] and in villages in four districts in Lao People's Democratic Republic.[24] Both of these studies predominantly used clinical markers for organ dysfunction. The study from Nepal also expanded the criteria for severe maternal complications to include severe postpartum hemorrhage, placenta previa and obstructed/prolonged labour.[16]

Although regional comparisons cannot not be made, the Haydom criteria was used in two studies in Tanzania[13] and Rwanda,[69] and the Papua New Guinea (PNG) criteria were used in the two studies from Oceania.[49 51] The Haydom criteria excluded six laboratory parameters (PaO2/FiO2, creatinine, bilirubin, pH, lactate and urine ketoacids) and two management interventions (vasoactive drugs and dialysis). The PNG criteria only excluded four laboratory parameters (PaO2/FiO2, pH, lactate and urine ketoacids).

Fifteen studies made qualitative remarks about challenges, of which five studies[72–76] did not make adaptations to the MNM criteria. The most commonly cited challenges were the absence of an ICU (four studies), lack of laboratory testing (four studies) and unavailability of blood products (two studies). Three studies also commented on the applicability of the MNM criteria in private facilities and lower level facilities due to limited facilities, the need to separate MNM cases on arrival hospital vs those that develop in the hospital setting and a need for MNM criteria at the community level.

DISCUSSION

We have included 60 studies from 56 countries in this meta-analysis with a pooled near-miss estimate using the WHO MNM criteria of 1.4% (95% CI 0.4% to 2.5%). We found that the near-miss rates differed between the SDG regions, with sub-Saharan Africa having the largest variation in range. While we expected a high degree of heterogeneity between the studies given the observational nature of the included studies and the fact that the studies were drawn from different hospital settings and from numerous countries around the world, our analysis of MNM rates by regional groupings did not find substantial in between study heterogeneity.

While the utilisation of the WHO MNM approach has increased over time, with 52.2% of papers on MNM published in 2017 using this approach, the WHO MNM criteria is predominantly used in low-resource countries.[6] Of the 60 studies we included in our review, only 4 studies were conducted in high-income countries (USA, Australia and New Zealand) and 19 studies were from upper-middle income countries. Of the 15 papers from the meta-analysis that made adaptations to the WHO MNM criteria, only one was from an upper middle income country. We found that a number of adaptations and modifications were made to the WHO MNM criteria in low-resource settings, particularly to laboratory investigations. Interventions such as dialysis and the continuous use of vasoactive drugs were excluded and almost two-thirds of the studies reduced the threshold for blood transfusion due to resource limitations. Our findings are in keeping with other reviews which have also found that the WHO MNM approach has mainly been used in Asian and African countries and rarely in North American and European countries.[6]

Our study builds on the 2012 WHO systematic review.[6] At that time, a meta-analysis of near miss could not be conducted because of the variety of identification criteria and as the WHO MNM criteria was only newly introduced, the previous review was limited in its assessment of the WHO MNM criteria. To our knowledge, there is one previous systematic review and meta-analysis that has looked at the global prevalence of MNM using the WHO MNM criteria.[77] Our study is more comprehensive in its scope as it includes a larger number of studies and did not have language or population restrictions while the other review included 49 studies, English language only and excluded studies that did not include a generalisable population . The review had a similar weighted pooled MNM prevalence (1.867% (95% CI 16.23% to 21.06%)) to ours but unlike us, the review found significant heterogeneity between studies in their regional analysis

Our paper is the first to bring together a meta-analysis and an examination of applications across different settings. We included a large number of papers in the meta-analysis as we did not have language restrictions. We analysed adaptations globally across all settings while previously published literature have focused on adaptations in sub-Saharan Africa only.[78] As we hypothesised that contextual adaptations to the WHO MNM criteria would be needed in low-resource settings, we conducted an additional search to capture more papers from these settings to fully understand the types of adaptations that are needed to operationalise the criteria with resource limitations.

One of the limitations of our analysis is that the denominators for MNM rate included both deliveries and live births. Using deliveries instead of live births in the denominator may result in underestimation of the MNM frequency. We did not examine the variation in the reported rates of MNM, which could also reflect differences in monitoring and reporting due to different

practices or patient populations.[6] We purposefully included studies prior to the COVID-19 pandemic in order to avoid bias from the impact of the pandemic on maternal health outcomes. The COVID-19 pandemic has had profound impact on healthcare systems and during this time, global maternal and fetal outcomes have worsened with an increase in maternal deaths and morbidity, particularly in low-resource settings.[79] MNM events could be another key indicator to study the impact of the pandemic.

As we continue to use MNM as an indicator to monitor the quality of obstetric care, there is a need to be aware of adaptations and modifications that are required in low-resource settings and interpret data accordingly. Some studies have also found that the application of the WHO MNM tool in low-resource settings has resulted in underreporting of life-threatening events, which are felt to be due to lack of blood for transfusion and lack of laboratory and diagnostic resources.[80] Although several of the WHO MNM parameters may not be applicable to low-resource settings, there is a lack of well-founded alternative parameters. In 2017, a Delphi consensus group was convened to develop an adapted set of criteria for Sub-Saharan Africa that focus more on clinical criteria rather than lab parameters.[80] While we have not identified any studies using this adapted tool, several studies have evaluated modified versions with a lower threshold for blood transfusion in low-resource settings and have found that lowering the threshold for blood transfusion leads to a higher detection rate of MNM and can provide a more consistent estimate of MNM incidence and mortality index.[70 81] Future directions could include integrating the use of ICD codes into WHO MNM criteria to help with standardisation, developing an integrative module for poor-resource health facilities and assessing the specificity, sensitivity, and predictive value of these adapted tools.

CONCLUSION

As countries progress through the stages of obstetric transition, and as maternal mortality decreases and women increasingly deliver in facilities, tracking and evaluating maternal morbidity, specifically, MNM is a necessary step in improving the quality of care. Strategies toward ending preventable maternal mortality (EPMM) and the Every Newborn Action Plan have been important efforts to set out agreed targets and priorities. These are now also embedded in the Global Strategy for Women's Children's and Adolescent's Health, and have gained political momentum in shaping national strategies. As part of this strategy, one of the cross-cutting actions is to improve metrics, measurement systems and data quality while one of the five strategic objectives is to address all causes of maternal mortality, reproductive and maternal morbidities and related disabilities. The WHO MNM concept (pragmatically or strictly defined) is useful to generate actionable information at the health service level, improve women's delivery experiences and outcomes and strengthenhealth systems. The WHO MNM criteria have enabled standardised case identification and allowed for the comparison of global and subnational estimates of MNM frequency and inform quality improvement efforts.

There has been good uptake of the WHO MNM criteria in low-resource settings but due to resource constraints in low-resource settings, there might be a need for local adaptation, where appropriate.

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Table S1: Study characteristics [N=60]

Study	Country (Study Period)	Setting	Study Design	No. Deaths	No. Near Miss	No. Deliveries	No. Live Births	% Near Miss	Near Miss/ Mortality Rate
Brown 2011	USA (1994-2005)	Teaching hospital	Cross-sectional retrospective	5	612	12774	--	4.79	122.40
Cecatti 2011	Brazil (2002-2007)	Tertiary care hospital	Cross-sectional retrospective	18	194	--	14413	1.35	10.78
Jayaratnam 2011	New Zealand (2009-2010)	Referral hospital	Cross-sectional prospective	--	17	--	2833	0.60	--
Morse 2011	Brazil (2009)	Tertiary care hospital	Cross-sectional prospective	3	10	--	1069	0.94	3.33
Jabir 2013	Iraq (2010)	Various public hospitals (municipal)	Cross-sectional prospective	16	129	--	25472	0.51	8.06
Lobato 2013	Brazil (2008)	Maternity hospital	Cross-sectional retrospective	8	27	--	812	3.33	3.38
Nelissen 2013	Tanzania (2009-2011)	Referral hospital	Cross-sectional prospective	32	216	9471	--	2.28	6.75
Oliveira 2013	Brazil (2007-2010)	Tertiary care Hospital	Cross-sectional retrospective	--	255	--	19940	1.28	--
Ps 2013	India (2011-2012)	Tertiary care hospital	Cross-sectional prospective	23	131	7390	--	1.77	5.70
Rana 2013	Nepal (2012)	Various tertiary care hospitals (municipal)	Cross-sectional prospective	26	157	--	41676	0.38	6.04

Table S1: Study characteristics [N=60]

Study	Country (Study Period)	Setting	Study Design	No. Deaths	No. Near Miss	No. Deliveries	No. Live Births	% Near Miss	Near Miss/ Mortality Rate
Shen 2013	China (2008-2012)	Teaching hospital	Cross-sectional retrospective	3	69	--	18104	0.38	23.00
Souza 2013	(2010-2011)	Various hospitals (national)	Cross-sectional prospective						
	Afghanistan			19	421	--	25227	1.67	22.16
	Angola			35	57	--	9966	0.57	1.63
	Argentina			9	51	--	9729	0.52	5.67
	Brazil			1	17	--	7019	0.24	17.00
	Cambodia			5	59	--	4635	1.27	11.80
	China			0	34	--	13242	0.26	--
	Democratic Republic of the Congo			27	88	--	8395	1.05	3.26
	Ecuador			9	30	--	10108	0.30	3.33
	India			109	174	--	30094	0.58	1.60
	Japan			0	21	--	3527	0.60	--
	Jordan			0	5	--	1158	0.43	--
	Kenya			55	77	--	19658	0.39	1.40
	Lebanon			2	18	--	4008	0.45	9.00
	Mexico			4	153	--	13167	1.16	38.25
	Mongolia			1	61	--	7303	0.84	61.00
	Nepal			8	65	--	10999	0.59	8.13
	Nicaragua			6	119	--	6426	1.85	19.83
	Nigeria			73	298	--	11775	2.53	4.08

Table S1: Study characteristics [N=60]

Study	Country (Study Period)	Setting	Study Design	No. Deaths	No. Near Miss	No. Deliveries	No. Live Births	% Near Miss	Near Miss/ Mortality Rate
	Occupied Palestinian Territory			0	3	--	975	0.31	--
	Pakistan			38	94	--	12729	0.74	2.47
	Paraguay			3	8	--	3595	0.22	2.67
	Peru			6	169	--	15021	1.13	28.17
	Philippines			12	29	--	10609	0.27	2.42
	Qatar			0	14	--	3932	0.36	--
	Sri Lanka			3	73	--	17988	0.41	24.33
	Thailand			2	51	--	8894	0.57	25.50
	Uganda			32	120	--	10467	1.15	3.75
	Viet Nam			0	33	--	15411	0.21	--
Abalos 2014	Argentina (2012)	Various hospitals (regional)	Cross-sectional	7	28	--	6024	0.46	4
Aziz 2014	India (2011-2012)	Referral hospital	Prospective observational	6	103	--	13219	0.77	17.17
Bastos Dias 2014	Brazil (2011-2012)	Various hospitals (national)	Cross-sectional	684	23747	--	2325394	1.02	34.72
Galvão 2014	Brazil (2011-2012)	Various hospitals (regional)	Cross-sectional	17	77	--	16243	0.47	4.53
Litorp 2014	Tanzania (2012)	Various hospitals (regional)	Cross-sectional	77	467	--	13121	3.55	6.06

Table S1: Study characteristics [N=60]

Study	Country (Study Period)	Setting	Study Design	No. Deaths	No. Near Miss	No. Deliveries	No. Live Births	% Near Miss	Near Miss/ Mortality Rate
Luexay 2014	Laos (2011)	Various hospitals (regional)	Prospective descriptive	2	11	--	1123	0.98	5.5
Pandey 2014	India (2011-2012)	University hospital	Retrospective	247	633	--	5273	12.0	2.56
Tunçalp 2014	Ghana (2010-2011)	Tertiary care hospital	Prospective cohort	37	94	--	3206	2.93	2.54
Bashour 2015	(2012-2013)	Various hospitals (national)	Cross-sectional						
	Egypt			3	32	--	2641	1.21	11.83
	Lebanon			0	5	--	1171	0.43	--
	Palestine			0	16	--	1244	1.29	--
	Syria			3	18	--	4007	0.45	6.00
Cecatti 2016	Brazil (2009-2010)	Various hospitals (national)	Cross-sectional prospective	140	770	--	82144	0.94	5.50
Karolinski 2015	Argentina (2013-2014)	Various hospitals (national)	Prevalence	8	67	--	9921	0.68	8.38
Kulkarni 2015	India (2012-2013)	Tertiary hospitals (regional)	Prospective observational	94	668	--	14508	4.60	7.11
Madeiro 2015	Brazil (2012-2013)	Tertiary hospital (regional)	Transversal	10	56	--	5841	0.96	5.60
Menezes 2015	Brazil (2011-2012)	Reference hospitals (regional)	Cross-sectional prospective	17	77	--	16243	0.47	4.53

Table S1: Study characteristics [N=60]

Study	Country (Study Period)	Setting	Study Design	No. Deaths	No. Near Miss	No. Deliveries	No. Live Births	% Near Miss	Near Miss/ Mortality Rate
Naderi 2015	Iran (2013)	Various hospitals (regional)	Prospective	2	501	--	19908	2.52	250.50
Oladapo 2015	Nigeria (2012-2013)	Various hospitals (national)	Cross-sectional prospective	998	1451	--	91724	1.58	1.45
Rulisa 2015	Rwanda (2011-2012)	Teaching tertiary hospital	Cross-sectional prospective	50	142	--	1739	8.17	2.84
Shahid 2015	Pakistan (2014)	Tertiary hospital (regional)	Retrospective	7	124	--	2371	5.23	17.71
Soma-Pillay 2015	South Africa (2013-2014)	Various hospitals (regional)	Descriptive population- based	19	117	26614	--	0.44	6.16
Abha 2016	India (2013-2015)	University hospital	Prospective observational	102	211	--	13895	1.52	2.07
De Mucio 2016	(2013)	Various hospitals (national)	Cross-sectional prospective						
	Argentina			0	2	--	762	0.26	--
	Colombia			0	3	--	334	0.90	--
	Dominican Republic			0	3	--	133	2.26	--
	Ecuador			0	2	--	228	0.88	--

Table S1: Study characteristics [N=60]

Study	Country (Study Period)	Setting	Study Design	No. Deaths	No. Near Miss	No. Deliveries	No. Live Births	% Near Miss	Near Miss/ Mortality Rate
	Honduras			1	10	--	613	1.63	10.00
	Nicaragua			0	4	--	477	0.84	--
	Paraguay			1	2	--	334	0.60	2.00
	Peru			0	11	--	315	3.49	--
El Ghardallou 2016	Tunisia (2012)	Tertiary care hospital	Cross-sectional retrospective	1	58	--	9890	0.59	58.00
Ghazivakili 2016	Iran (2012)	Various hospitals (regional)	Cross-sectional prospective	7	192	--	38663	0.50	27.43
Jayaratnam 2016	Australia (2014-2015)	Tertiary teaching hospital	Prospective observational	1	10	--	2080	0.48	10.00
Kalisa 2016	Rwanda (2013-2014)	Provincial referral hospital	Prospective cohort	13	86	--	3994	2.15	6.62
Nakimuli 2016	Uganda (2013-2014)	Referral hospitals (national)	Prospective cohort	130	695	--	25840	2.69	5.35
Nanda 2016	India (2012-2014)	Tertiary hospitals (national)	Prospective observational	60	184	--	13851	1.33	3.07

Table S1: Study characteristics [N=60]

Study	Country (Study Period)	Setting	Study Design	No. Deaths	No. Near Miss	No. Deliveries	No. Live Births	% Near Miss	Near Miss/ Mortality Rate
Norhayati 2016	Malaysia (2014)	Tertiary hospitals (national)	Cross-sectional prospective	2	47	21579	--	0.22	23.50
Parmar 2016	India (2012)	Tertiary care hospital	Cross-sectional prospective	18	40	--	1929	2.07	2.22
Rathod 2016	India (2011-2013)	Tertiary care hospital	Cohort retrospective	66	161	--	22092	0.73	2.44
Tanimia 2016	Papua New Guinea (2012-2013)	Teaching hospital	Prospective observational	9	122	--	13338	0.91	13.56
Akrawi 2017	Iraq (2013)	Tertiary care hospital	Cross-sectional prospective	11	142	--	17353	0.82	12.91
Bolnga 2017	Papua New Guinea (2014-2016	Provincial hospital	Prospective observational study	10	153	--	6019	2.54	15.30
Herklots 2017	Tanzania (2016)	Tertiary care hospital	Cross-sectional prospective	28	37	--	4125	0.90	1.32
Liyew 2017	Ethiopia (2015-2016)	Various hospitals (regional)	Cross-sectional prospective	--	238	29697	--	0.80	--

Table S1: Study characteristics [N=60]

Study	Country (Study Period)	Setting	Study Design	No. Deaths	No. Near Miss	No. Deliveries	No. Live Births	% Near Miss	Near Miss/ Mortality Rate
Mbachu 2017	Nigeria (2014-2015)	Referral hospital	Cross-sectional prospective	5	52	262	--	19.85	10.40
Serruya 2017	Multicountry (2009-2012)	Various hospitals (national)	Cross-sectional retrospective	1028	21985	697820	--	3.15	21.39
Chikadaya 2018	Zimbabwe	Various hospitals (regional)	Prospective descriptive	13	110	11871	--	0.92	8.46
Esparza-Valencia 2018	Mexico (2016)	Secondary care hospital	Cross sectional Retrospective	5	362	--	4691	7.72	72.4
Iwuh 2018	South Africa (2014)	Various hospitals (regional)	Retrospective observational	13	112	19222	--	0.58	8.62
Jayaratnam 2018	Australia	University hospital	Prospective observational	0	19	--	2773	0.69	--
Rana 2018	Nepal (2015)	Various hospitals (regional)	Mixed methods	1	21	--	1386	1.52	21
Reena 2018	India	University hospital	Cross-sectional	5	32	--	3451	0.92	6.4
Schwenck 2018	Brazil (2017-2018)	High-risk maternity	Cross-sectional prospective	4	51	--	1493	3.42	12.75
Sheriar 2018	India	Tertiary care hospital	Prospective observational	15	250	--	8070	3.09	16.67

Table S1: Study characteristics [N=60]

Study	Country (Study Period)	Setting	Study Design	No. Deaths	No. Near Miss	No. Deliveries	No. Live Births	% Near Miss	Near Miss/ Mortality Rate
Tura 2018	Ethiopia (2016-2017)	Referral hospital	Prospective cohort	26	128	--	7404	1.73	4.92
Verschueren 2018	Suriname (2017)	Various hospitals (national)	Prospective cohort	4	32	--	3330	0.96	8
Woldeyes 2018	Ethiopia	Referral hospital	Prospective cross-sectional	24	138	--	2737	5.04	5.75

Table S2: Quality assessment [N=60 studies]

STUDY NAME	FIRST AUTHOR/ YEAR	Was the research question or objective in this paper clearly stated?	Was the study population clearly specified and defined?	Was the participation rate of eligible persons at least 50%?	Were all the subjects selected or recruited from the same or similar populations (including the same time period)?	Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	Was a sample size justification, power description, or variance and effect estimates provided?	Quality Rating (Good, Fair, or Poor)
Near miss maternal mortality in a multiethnic population	Brown 2011	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
Pre-validation of the WHO organ dysfunction based criteria for identification of maternal near miss	Cecatti 2011	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
Developing an assessment tool for maternal morbidity 'near-miss'- a prospective study in a large Australian regional hospital	Jayaratnam 2011	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
Severe maternal morbidity and near misses in a regional reference hospital.	Morse 2011	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
Severe acute maternal morbidity: use of the Brazilian Hospital Information System.	Magalhaes 2012	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
Maternal near miss and quality of maternal health care in Baghdad, Iraq.	Jabir 2013	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
Comparing different diagnostic approaches to severe maternal morbidity and near-miss: a pilot study in a Brazilian tertiary hospital.	Lobato 2013	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
Maternal near miss and mortality in a rural referral hospital in Northern Tanzania: a cross-sectional study.	Nelissen 2013	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
Fetal and neonatal deaths among cases of maternal near miss	Oliveira 2013	Yes	Yes	Yes	Yes	Yes	Yes	Good

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Near miss" obstetric events and maternal deaths in a tertiary care hospital: an audit.	Ps 2013	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
Maternal near-miss: A multicenter surveillance in Kathmandu valley	Rana 2013	Yes	Cannot Determine	Yes	Cannot Determine	Yes	Not Reported	Fair
Factors associated with maternal near-miss morbidity and mortality in Kowloon Hospital, Suzhou, China	Shen 2013	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
Moving beyond essential interventions for reduction of maternal mortality (the WHO Multicountry Survey on Maternal and Newborn Health): a cross-sectional study	Souza 2013	Yes	Yes	Yes	Yes	Yes	Yes	Good
Assessment of maternal near miss and quality of care in a hospital-based study in Accra, Ghana	Tuncalp 2013	Yes	Yes	Yes	Yes	Yes	Yes	Good
Morbilidad severa materna y neonatal: vigilancia en servicios y capacidad de respuesta del sistema de salud	Abalos 2014	Yes	Yes	Yes	Yes	Yes	No	Fair
Comparison of etiology of maternal near miss in a tertiary referral centre in booked and referred population	Aziz 2014	Yes	Yes	Yes	Yes	Yes	No	Fair
Incidence of maternal near miss in hospital childbirth and postpartum: Data from the Birth in Brazil study	Bastos Dias 2014	Yes	Yes	Yes	No	Yes	Yes	Good

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STUDY NAME	FIRST AUTHOR/ YEAR	Was the research question or objective in this paper clearly stated?	Was the study population clearly specified and defined?	Was the participation rate of eligible persons at least 50%?	Were all the subjects selected or recruited from the same or similar populations (including the same time period)?	Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	Was a sample size justification, power description, or variance and effect estimates provided?	Quality Rating (Good, Fair, or Poor)
The prevalence of severe maternal morbidity and near miss and associated factors in Sergipe, Northeast Brazil	Galvão 2014	Yes	Yes	Yes	Yes	Yes	No	Fair
Maternal near-miss and death and their association with caesarean section complications: A cross sectional study at a university hospital and a regional hospital in Tanzania	Litorp 2014	Yes	Yes	Yes	Yes	Yes	No	Fair
Maternal near-miss and mortality in Sayaboury Province, Lao PDR	Luexay 2014	Yes	Yes	Yes	Yes	Yes	No	Fair
Evaluation of Obstetric Near Miss and Maternal Deaths in a Tertiary Care Hospital in North India: Shifting Focus from Mortality to Morbidity	Pandey 2014	Yes	Yes	Yes	Yes	Yes	No	Fair
A cross sectional study of maternal 'near-miss' cases in major public hospitals in Egypt, Lebanon, Palestine and Syria.	Bashour 2015	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
Network for Surveillance of Severe Maternal Morbidity: a powerful national collaboration generating data on maternal health outcomes and care	Cecatti 2016	Yes	Yes	Yes	Yes	Yes	Yes	Good
Bases para establecer un sistema de vigilancia activa y respuesta rápida para el manejo de la morbilidad materna severa.	Karolinski 2015	Yes	Yes	Yes	Yes	Yes	Not Reported	Good

Table S2: Quality assessment [N=60 studies]

STUDY NAME	FIRST AUTHOR/ YEAR	Was the research question or objective in this paper clearly stated?	Was the study population clearly specified and defined?	Was the participation rate of eligible persons at least 50%?	Were all the subjects selected or recruited from the same or similar populations (including the same time period)?	Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	Was a sample size justification, power description, or variance and effect estimates provided?	Quality Rating (Good, Fair, or Poor)
Prospective observational study of near-miss obstetric events at two tertiary hospitals in Mumbai, Maharashtra, India	Kulkarni 2015	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
Incidence and determinants of severe maternal morbidity: a transversal study in a referral hospital in Teresina, Piaui, Brazil.	Madeiro 2015	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
Similarities and differences between WHO criteria and two other approaches for maternal near miss diagnosis	Menezes 2015	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
Incidence and correlates of maternal near miss in southeast Iran.	Naderi 2015	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
When getting there is Not enough: a nationwide cross-sectional study of 998 maternal deaths and 1451 near-misses in public tertiary hospitals in a low-income country	Oladapo 2015	Yes	Yes	Yes	Yes	Yes	Not Reported	Good
Maternal near miss and mortality in a tertiary care hospital in Rwanda	Rulisa 2015	Yes	Yes	Yes	Yes	Yes	No	Good
Near miss events frequency and most common causes.	Shahid 2015	No	No	Yes	Yes	Yes	No	Poor
Maternal near miss and maternal death in the Pretoria Academic Complex, South Africa: A population-based study	Soma-Pillay 2015	Yes	Yes	Yes	Yes	Yes	No	Fair

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Maternal Near Miss: A Valuable Contribution in Maternal Care.	Abha 2016	Yes	No	Yes	Yes	Yes	No	Poor
Maternal near miss and predictive ability of potentially life-threatening conditions at selected maternity hospitals in Latin America.	De Mucio 2016	Yes	Yes	Yes	Yes	Yes	No	Fair
Maternal Near Miss and Quality of Obstetric Care in a Tunisian Tertiary Level Maternity.	El Ghardallou 2016	Yes	Yes	Yes	Yes	Yes	No	Fair
Maternal near miss approach to evaluate quality of care in Alborz province, Iran.	Ghazivakili 2016	Yes	Yes	Yes	Yes	Yes	Yes	Good
Maternal 'near miss' at Royal Darwin Hospital: An analysis of severe maternal morbidity at an Australian regional tertiary maternity unit	Jayaratnam 2016	Yes	Yes	Yes	Yes	Yes	No	Fair
Maternal Near Miss and quality of care in a rural Rwandan hospital	Kalisa 2016	Yes	Yes	Yes	Yes	Yes	No	Fair
Maternal near misses from two referral hospitals in Uganda: a prospective cohort study on incidence, determinants and prognostic factors	Nakimuli 2016	Yes	Yes	Yes	Yes	Yes	Yes	Good
A prospective observational study of near miss events and maternal deaths in a tertiary hospital in India [Conference Abstract]	Nanda 2016	Yes	Yes	Yes	Yes	Yes	No	Fair

Table S2: Quality assessment [N=60 studies]

STUDY NAME	FIRST AUTHOR/ YEAR	Was the research question or objective in this paper clearly stated?	Was the study population clearly specified and defined?	Was the participation rate of eligible persons at least 50%?	Were all the subjects selected or recruited from the same or similar populations (including the same time period)?	Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	Was a sample size justification, power description, or variance and effect estimates provided?	Quality Rating (Good, Fair, or Poor)
Severe maternal morbidity and near misses in tertiary hospitals, Kelantan, Malaysia: a cross-sectional study.	Norhayati 2016	Yes	Yes	Yes	Yes	Yes	Yes	Good
Incidence of Maternal "Near-Miss" Events in a Tertiary Care Hospital of Central Gujarat, India.	Parmar 2016	Yes	Cannot Determine	Yes	Yes	Yes	No	Poor
Analysis of near-miss and maternal mortality at tertiary referral centre of rural India.	Rathod 2016	No	Yes	Yes	Yes	Yes	No	Poor
Near-misses at the Port Moresby General Hospital: a descriptive study	Tanimia 2016	Yes	Yes	Yes	Yes	Yes	No	Fair
Major Determinants of Maternal Near-Miss and Mortality at the Maternity Teaching Hospital, Erbil city, Iraq.	Akrawi 2017	Yes	Yes	Yes	Yes	Yes	No	Fair
Maternal near-misses at a provincial hospital in Papua New Guinea: A prospective observational study	Bolnga 2017	Yes	Yes	Yes	Yes	Yes	No	Fair
Severe maternal morbidity in Zanzibar's referral hospital: Measuring the impact of in hospital care	Herklots 2017	Yes	Yes	Yes	Yes	Yes	Yes	Good
Maternal near-miss audit in the Metro West maternity service, Cape Town, South Africa: A retrospective observational study	Iwuh 2017	Yes	Yes	Yes	Yes	Yes	Yes	Good
Incidence and causes of maternal near-miss in selected hospitals of Addis Ababa, Ethiopia.	Liyew 2017	Yes	Yes	Yes	Yes	Yes	Yes	Good

Table S2: Quality assessment [N=60 studies]

STUDY NAME	FIRST AUTHOR/ YEAR	Was the research question or objective in this paper clearly stated?	Was the study population clearly specified and defined?	Was the participation rate of eligible persons at least 50%?	Were all the subjects selected or recruited from the same or similar populations (including the same time period)?	Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	Was a sample size justification, power description, or variance and effect estimates provided?	Quality Rating (Good, Fair, or Poor)
A cross sectional study of maternal near miss and mortality at a rural tertiary centre in southern Nigeria	Mbachu 2017	Yes	Yes	Yes	Yes	Yes	No	Fair
Exploring the Concept of Degrees of Maternal Morbidity as a Tool for Surveillance of Maternal Health in Latin American and Caribbean Setting	Serruya 2017	Yes	Yes	Yes	Yes	Yes	No	Fair
Incidence of maternal near miss in the public health sector of Harare, Zimbabwe: a prospective descriptive study	Chikadaya 2018	Yes	Yes	Yes	Yes	Yes	No	Fair
Prevalence of extreme maternal morbidity in a second-level hospital in san luis potosí, méxico.	Esparza Valencia 2018	Yes	Yes	Yes	Yes	Yes	Yes	Good
Maternal 'near miss' collection at an Australian tertiary maternity hospital	Jayaratnam 2018	Yes	Yes	Yes	Yes	Yes	No	Fair
Assessing maternal and neonatal near-miss reviews in rural Nepal: an implementation research study to inform scale-up	Rana 2018	Yes	Yes	Yes	Yes	Yes	No	Fair
Factors associated with maternal near miss: A study from Kerala	Reena 2018	Yes	Yes	Yes	Yes	Yes	No	Fair
A cross sectional study of maternal near miss cases at a high-risk maternity in Brazil	Schwenck 2018	Yes	Yes	Yes	Yes	Yes	No	Fair
Maternal near miss in a tertiary care hospital	Sheriar 2018	Yes	Yes	Yes	Yes	Yes	No	Fair

Table S2: Quality assessment [N=60 studies]

STUDY NAME	FIRST AUTHOR/ YEAR	Was the research question or objective in this paper clearly stated?	Was the study population clearly specified and defined?	Was the participation rate of eligible persons at least 50%?	Were all the subjects selected or recruited from the same or similar populations (including the same time period)?	Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	Was a sample size justification, power description, or variance and effect estimates provided?	Quality Rating (Good, Fair, or Poor)
Severe maternal outcomes in eastern Ethiopia: Application of the adapted maternal near miss tool	Tura 2018	Yes	Yes	Yes	Yes	Yes	No	Fair
Severe maternal morbidity & near-miss in suriname-interim of prospective national cohort study	Verschueren 2018	Yes	Yes	Yes	Yes	Yes	No	Fair
Incidence and determinants of severe maternal outcome in Jimma University teaching hospital, south-West Ethiopia: A prospective cross-sectional study	WoldeYes 2018	Yes	Yes	Yes	Yes	Yes	Yes	Good

Table S3: Near miss frequency per 1000 live births* by SDG Region [N=60 studies]

Country	Near miss frequency (range)	No. of studies**
Central and Southern Asia		
Afghanistan	1.67	1
India	5.8 - 120	11
Iran	5.0 - 25.2	2
Nepal	3.8 - 15.2	3
Pakistan	7.4 - 52.3	2
Sri Lanka	4.1	1
Eastern and South Eastern Asia		
Cambodia	12.7	1
China	2.6 - 3.8	2
Japan	6.0	1
Laos	9.8	1
Malaysia	2.2	1
Mongolia	8.4	1
Philippines	2.7	1
Thailand	5.7	1
Vietnam	2.1	1
Sub Saharan Africa		
Angola	5.7	1
Democratic Republic of the Congo	15.0	1
Ethiopia	8.0 - 50.4	3
Ghana	29.3	1
Kenya	0.39	1
Niger	18.3	1
Nigeria	15.8 - 198.5	3
Rwanda	21.5 - 81.7	2
South Africa	4.4 - 5.8	2
Tanzania	9.0 - 35.5	3
Uganda	11.5 - 26.9	2
Zimbabwe	9.2	1
Latin America and the Caribbean		
Argentina	2.6 - 6.8	4
Brazil	2.4 - 34.2	11
Colombia	9.0	1
Dominican Republic	22.6	1
Ecuador	3.0 - 8.8	2
Honduras	16.3	1
Mexico	11.6- 77.2	2
Nicaragua	8.4 - 18.5	2
Paraguay	2.2 - 6.0	2
Peru	11.3- 34.9	2
Suriname	9.6	1
Northern Africa and Western Asia		
Egypt	12.1	1
Iraq	5.1-8.2	2
Jordan	4.3	1
Lebanon	4.3- 4.5	2
Occupied Palestinian Territory	3.1 to 12.9	2

Table S3: Near miss frequency per 1000 live births by SDG Region [N=60 studies]

Country	Near miss frequency (range)	No. of studies
Qatar	3.6	1
Syria	4.5	1
Tunisia	5.9	1
Oceania		
Australia	4.8- 6.9	2
New Zealand	6.0	1
Papua New Guinea	9.1- 25.4	2
Europe and Northern America		
USA	47.9	1

*except 10 studies which reported number of deliveries

** total number of studies exceeds 60 as some studies included data from multiple countries

Table S4a: Near Miss meta-analysis [N=57 studies]

Country	Study	ES	[95% Conf. Interval]	% Weight
Sub-Saharan Africa				
Angola	Souza 2013	0.006	-0.254 0.265	0.16
DRC	Souza 2013	0.010	-0.198 0.219	0.24
Ethiopia	Liyew 2017	0.008	-0.119 0.135	0.65
Ethiopia	Tura 2018	0.017	-0.156 0.191	0.35
Ethiopia	Woldeyes 2018	0.050	-0.116 0.217	0.38
Ghana	Tuncalp 2014	0.029	-0.173 0.231	0.26
Kenya	Souza 2013	0.004	-0.219 0.227	0.21
Niger	Souza 2013	0.018	-0.122 0.158	0.54
Nigeria	Mbachu 2017	0.198	-0.073 0.470	0.14
Nigeria	Oladapo 2015	0.016	-0.036 0.067	3.99
Nigeria	Souza 2013	0.025	-0.088 0.139	0.82
Rwanda	Kalisa 2016	0.022	-0.190 0.233	0.24
Rwanda	Rulisa 2015	0.082	-0.083 0.246	0.39
South Africa	Iwuh 2018	0.006	-0.179 0.191	0.31
South Africa	Soma-P 2015	0.004	-0.177 0.186	0.32
Tanzania	Herklots 2017	0.009	-0.313 0.331	0.10
Tanzania	Litorp 2014	0.036	-0.055 0.126	1.28
Tanzania	Nelissen 2013	0.023	-0.111 0.156	0.59
Uganda	Nakimuli 2016	0.027	-0.047 0.101	1.91
Uganda	Souza 2013	0.011	-0.167 0.190	0.33
Zimbabwe	Chikadaya 2018	0.009	-0.178 0.196	0.30
Sub-total I-V pooled ES		0.024	-0.004 0.052	13.52
Northern Africa & Western Asia				
Egypt	Bashour 2015	0.012	-0.334 0.359	0.09
Iraq	Akrawi 2017	0.008	-0.156 0.173	0.39
Iraq	Jabir 2013	0.005	-0.168 0.178	0.35
Jordan	Souza 2013	0.004	-0.872 0.881	0.01
Lebanon	Bashour 2015	0.004	-0.872 0.881	0.01
Lebanon	Souza 2013	0.004	-0.457 0.466	0.05
OPT	Bashour 2015	0.013	-0.477 0.503	0.04
OPT	Souza 2013	0.003	-1.129 1.135	0.01
Qatar	Souza 2013	0.004	-0.520 0.527	0.04
Syria	Bashour 2015	0.004	-0.457 0.466	0.05
Tunisia	El Ghardall 2016	0.006	-0.251 0.263	0.16
Sub-total I-V pooled ES		0.007	-0.087 0.100	1.21
Central & Southern Asia				
Afghanistan	Souza 2013	0.017	-0.079 0.112	1.16
India	Abha 2016	0.015	-0.120 0.150	0.58
India	Aziz 2014	0.008	-0.185 0.201	0.28
India	Kulkarni 2015	0.046	-0.030 0.122	1.84
India	Nanda 2016	0.013	-0.131 0.158	0.51
India	Parmar 2016	0.021	-0.289 0.331	0.11
India	Ps 2013	0.018	-0.154 0.189	0.36
India	Rathod 2016	0.007	-0.147 0.162	0.44
India	Reena 2018	0.009	-0.337 0.356	0.09
India	Souza 2013	0.006	-0.143 0.154	0.48

Table S4a: Near Miss meta-analysis [N=57 studies]

Iran	Ghazivakili 2012	0.005	-0.136 0.146	0.53
Iran	Naderi 2015	0.025	-0.062 0.113	1.38
Nepal	Rana 2013	0.004	-0.153 0.160	0.43
Nepal	Rana 2018	0.015	-0.413 0.443	0.06
Nepal	Souza 2013	0.006	-0.237 0.249	0.18
Pakistan	Shahid 2015	0.052	-0.124 0.228	0.34
Pakistan	Souza 2013	0.007	-0.195 0.210	0.26
Sri Lanka	Souza 2013	0.004	-0.225 0.233	0.20
Sub-total I-V pooled ES		0.022	-0.012 0.055	9.21
Eastern & South-Eastern Asia				
Cambodia	Souza 2013	0.013	-0.242 0.268	0.16
China	Shen 2013	0.004	-0.232 0.240	0.19
China	Souza 2013	0.003	-0.334 0.339	0.09
Japan	Souza 2013	0.006	-0.422 0.434	0.06
Laos	Luexay 2014	0.010	-0.581 0.601	0.03
Malaysia	Norhayati 2016	0.002	-0.284 0.288	0.13
Mongolia	Souza 2013	0.008	-0.243 0.259	0.17
Philippines	Souza 2013	0.003	-0.361 0.367	0.08
Thailand	Souza 2013	0.006	-0.269 0.280	0.14
Viet Nam	Souza 2013	0.002	-0.339 0.343	0.09
Sub-total I-V pooled ES		0.006	-0.090 0.102	1.14
Latin America & the Caribbean				
Argentina	Abalos 2014	0.005	-0.366 0.375	0.08
Argentina	De Mucio 2016	0.003	-1.383 1.389	0.01
Argentina	Karolinsk 2015	0.007	-0.233 0.246	0.18
Argentina	Souza 2013	0.005	-0.269 0.280	0.14
Brazil	Bastos Dias 2014	0.010	-0.003 0.023	65.25
Brazil	Cecatti 2011	0.013	-0.127 0.154	0.53
Brazil	Cecatti 2015	0.009	-0.061 0.080	2.12
Brazil	Galvao 2014	0.005	-0.219 0.228	0.21
Brazil	Lobato 2013	0.033	-0.344 0.410	0.07
Brazil	Madeiro 2015	0.010	-0.252 0.271	0.15
Brazil	Menezes 2015	0.005	-0.219 0.228	0.21
Brazil	Morse 2011	0.009	-0.610 0.629	0.03
Brazil	Oliveira 2013	0.013	-0.110 0.136	0.70
Brazil	Souza 2013	0.002	-0.473 0.478	0.05
Brazil	Schwenck 2018	0.034	-0.240 0.309	0.14
Colombia	De Mucio 2016	0.009	-1.123 1.141	0.01
DR	De Mucio 2016	0.023	-1.109 1.154	0.01
Ecuador	Souza 2013	0.003	-0.355 0.361	0.08
Ecuador	De Mucio 2016	0.009	-1.377 1.395	0.01
Honduras	De Mucio 2016	0.016	-0.603 0.636	0.03
Mexico	Esparza-Valencia 2018	0.077	-0.026 0.180	0.99
Mexico	Souza 2013	0.012	-0.147 0.170	0.42
Nicaragua	Souza 2013	0.019	-0.161 0.198	0.33
Nicaragua	De Mucio 2016	0.008	-0.972 0.988	0.01
Paraguay	Souza 2013	0.002	-0.691 0.695	0.02
Paraguay	De Mucio 2016	0.006	-1.380 1.392	0.01
Peru	Souza 2013	0.011	-0.140 0.162	0.46
Peru	De Mucio 2016	0.035	-0.556 0.626	0.03

Table S4a: Near Miss meta-analysis [N=57 studies]

Suriname	Verschueren 2018	0.010	-0.337	0.356	0.09
Sub-total I-V pooled ES		0.011	-0.001	0.023	72.36
Oceania					
Australia	Jayaratnam 2016	0.005	-0.615	0.625	0.03
Australia	Jayaratnam 2016	0.007	-0.443	0.456	0.05
New Zealand	Jayaratnam 2016	0.006	-0.469	0.481	0.05
PNG	Bolnga 2017	0.025	-0.133	0.184	0.42
PNG	Tanimia 2016	0.009	-0.168	0.187	0.34
Sub-total I-V pooled ES		0.016	-0.093	0.126	0.88
Europe & Northern America					
USA	Brown 2011	0.048	-0.031	0.127	1.68
Sub-total I-V pooled ES		0.048	-0.031	0.127	1.68
Overall I-V pooled ES		0.014	**0.004**	**0.025**	**100.00**

Table S4b: Test of heterogeneity

Region	**Degrees of Freedom**	**P**	**I-Squared**	**%**
Sub-Saharan Africa	2.59	20	1.000	0.0%
Northern Africa & Western Asia	0.00	10	1.000	0.0%
Central & Southern Asia	0.82	17	1.000	0.0%
Eastern & South-Eastern Asia	0.01	9	1.000	0.0%
Latin America & the Caribbean	1.67	28	1.000	0.0%
Oceania	0.02	4	1.000	0.0%
Europe & Northern America	0.00	0	-	-
Overall	6.74	94	1.000	0.0%
Overall Test for heterogeneity between sub-groups:	**1.62**	**6**	**0.951**	**--**

Significance test of ES=0		
Region	**Z**	**p**
Sub-Saharan Africa	1.67	0.094
Northern Africa & Western Asia	0.14	0.886
Central & Southern Asia	1.25	0.212
Eastern & South-Eastern Asia	0.12	0.907
Latin America & the Caribbean	1.82	0.069
Oceania	0.30	0.768
Europe & Northern America	1.19	0.236
Overall	**2.75**	**0.006**

Table S5: Modifications and adaptions of the WHO MNM criteria [N=20]

Study	Severe Maternal Complications	Adaptations		
		Life Threatening Conditions (near miss criteria)		
		Criteria removed	Criteria added	Modifications made to criteria
Sub-Saharan Africa				
Benimama 2018 (Rwanda)	-Uterine infections leading to hysterectomy -Uterine and debridement repair	None	None	Transfusion of blood of ≥ 2 units orred cells
Herklots 2017 (Tanzania)	None	-Lactate >5 mmol or >45 mg/L -pH < 7.1 -PAO2/FiO2 <200 mmHg	None	None
Kalisa 2016 (Rwanda)	Abortion or ectopic pregnancy	-Lactate >5 mmol or >45 mg/L -pH < 7.1 -PAO2/FiO2 <200 mmHg -ketones in urines -dialysis for acute renal failure (ARF)	None	None
Litorp 2014 (Tanzania)	Cesarean section (CS) complications -complications specific to surgery or anesthesia -complications not specific to surgery or anesthesia but with an increased risk after CS (PPH leading to shock, hysterectomy, blood transfusion) -pre-existing condition that might have affected an outcome	<u>University teaching hospital</u> -Lactate >5 mmol or >45 mg/L -pH < 7.1 -PAO2/FiO2 <200 mmHg - dialysis for ARF <u>Regional hospital</u> -Lactate >5 mmol or >45 mg/L -pH < 7.1 -Oxygen saturation <90% for > 60 mins -PAO2/FiO2 <200 mmHg -Creatinine > 300 mmol/dl or > 3.5 mg/dl -bilirubin >100 umol/l or >6.0mg/dl	None	All types of blood products included in massive transfusion

Table S5: Modifications and adaptions of the WHO MNM criteria [N=20]

Study	Severe Maternal Complications	Adaptations		
		Life Threatening Conditions (near miss criteria)		
		Criteria removed	Criteria added	Modifications made to criteria
		-platelets <50,000 -glucose and ketoacids in urine -use of continuous use of vasoactive drugs -dialysis for ARF		
Mbachu 2017 (Nigeria)	Obstructed labour	None	None	None
Nakamuli 2016 (Uganda)	None	-Uncontrollable fits/status epilepticus	-Hospitalization >7 d -Admission to HDU or ICU -Referral to a more specialized unit -Return to operation theatre -Major operative non-obstetric surgery	Blood transfusion of ≥ 4 units of blood
Nelissen 2013 (Tanzania)	None	-Lactate >5 mmol or >45 mg/L -pH < 7.1 -PAO2/FiO2 <200 mmHg -Creatinine > 300 mmol/dl or > 3.5 mg/dl -bilirubin >100 umol/l or >6.0mg/dl -glucose and ketoacids in urine -use of continuous vasoactive drugs -dialysis for ARF	None	Blood transfusion of ≥ 1 unit of blood

Table S5: Modifications and adaptions of the WHO MNM criteria [N=20]

Study	Severe Maternal Complications	Adaptations		
		Life Threatening Conditions (near miss criteria)		
		Criteria removed	Criteria added	Modifications made to criteria
Owlabi 2017 (Zambia)	Incomplete, complete, missed, septic, inevitable or spontaneous abortion hospitalized for > 24 hours	None	-muco-cutaneous signs -clinical diagnosis of septicemia or one of the following: t> 39°C, t <36°C, genital infection AND one of the following: systolic BP <90 mmHg, icterus, altered consciousness, oliguria <100 mL in 4h -anemia <4 g/dL -anemia in combination with blood transfusion (4-6.9 g/dL) with blood transfused ≥ 1 unit -uterine output <30 ml/h for 4h or <400 ml/24 h -uterine perforation -bowel injury	Blood transfusion of ≥ 2 units of blood
Sayingoza 2017 (Rwanda)	None	-Lactate >5 mmol or >45 mg/L -pH < 7.1 -PAO2/FiO2 <200 mmHg -Creatinine > 300 mmol/dl or > 3.5 mg/dl -bilirubin ≥ 100 umol/l or >6.0mg/dl -glucose and ketoacids in urine -use of continuous -vasoactive drugs -dialysis for ARF	None	Transfusion of ≥ 1 unit of blood

Table S5: Modifications and adaptions of the WHO MNM criteria [N=20]

Study	Severe Maternal Complications	Adaptations		
		Life Threatening Conditions (near miss criteria)		
		Criteria removed	Criteria added	Modifications made to criteria
Tura 2018 (Ethiopia)	-Severe malaria -Pulmonary edema -Severe pre-eclampsia with ICU admission	-lactate >5 mmol or >45 mg/L -pH < 7.1 -PAO2/FiO2 <200 mmHg -bilirubin > 100 umol/l or >6.0mg/dl - use of continuous vasoactive drugs -dialysis for ARF	None	Transfusion of ≥ 2 units of blood
Wittevan 2017 (Malawi & Tanzania)	None	None	None	Transfusion of ≥ 1unit of blood
Van den Akker 2013 (Malawi)	-Uterine rupture after vaginal birth -IUFD leading to laparotomy -Eclampsia or severe pre-eclampsia with maternal indication for termination of pregnancy -Major obstetric hemorrhage (including from complicated abortion and ectopic pregnancies) -Severe obstetric and non-obstetric peripartum infections -Any complications the clinical considered severe	None	None	-Transfusion of ≥ 2 units of blood -Hemoglobin <6 g/dL after vaginal bleeding or an estimated blood loss of >1L
Northern Africa and Western Asia				
Akrawi 2017 (Iraq)	-Severe forms of complications of abortion -Ectopic pregnancy -Abruption placentae -Placenta previa	None	Anemia with Hb <6g/dL or clinical signs of severe anemia in women without severe hemorrhage	Transfusion of ≥ 3 units of bloodproduct

Table S5: Modifications and adaptions of the WHO MNM criteria [N=20]

Study	Severe Maternal Complications	Adaptations		
		Life Threatening Conditions (near miss criteria)		
		Criteria removed	Criteria added	Modifications made to criteria
Central and Southern Asia				
Kulkarni 2016 (India)	None	None	Severe anemia with hemoglobin 60 g/L or clinical signs of severe anemia without hemorrhage	None
Pandey 2014 (India)	None	-pH < 7.1 -PAO2/FiO2 <200 mmHg	None	None
Rana 2018 (Nepal)	Severe PPH ≥ 1000 mL of blood loss (or four fully soaked pads in 30 minutes) APH (placenta praevia) requiring blood transfusion Obstructed/prolonged labour >18 hours	-continuous vasoactive drugs -CPR - Lactate >5 mmol/l or >45 mg/dl -pH <7.1 -intubation and ventilation not related to anaesthesia - PAO2/FiO2 <200 mmHg - dialysis for acute renal failure -Creatinine ≥300 µmol/ml or ≥3.5 mg/dl -massive transfusion of blood or red cells (≥5 units) -platelets <50,000 - bilirubin ≥ 100 umol/l or >6.0mg/dl -Uterine haemorrhage or infection leading to hysterectomy		

Table S5: Modifications and adaptions of the WHO MNM criteria [N=20]

Study	Severe Maternal Complications	Adaptations		
		Life Threatening Conditions (near miss criteria)		
		Criteria removed	Criteria added	Modifications made to criteria
Eastern and South-Eastern Asia				
Luexay 2014 (Lao PDR)	None	-pH < 7.1 -PAO2/FiO2 <200 mmHg -lactate >5 mmol or >45 mg/L -bilirubin ≥ 100 umol/l or >6.0mg/dl -intubation and ventilation not related to anesthesia -continuous use of vasoactive drugs -dialysis for ARF -massive transfusion of blood or PRBCs -CPR -gasping -failure to form clots -uncontrollable fit/status epilepticus -uterine infection or hemorrhage leading to Hysterectomy	None	Excessive bleeding per vagina
Shen 2013 (China)	None	-pH < 7.1 -lactate >5 mmol or >45 mg/L -blood transfusion of less than 5 units -intubation related to anesthesia -loss of consciousness for less than 12 hours	None	Pre-eclampsia without jaundice not included

Table S5: Modifications and adaptions of the WHO MNM criteria [N=20]

Study	Severe Maternal Complications	Adaptations		
		Life Threatening Conditions (near miss criteria)		
		Criteria removed	Criteria added	Modifications made to criteria
Oceania				
Bolgna 2017 (Papua New Guinea)	None	-pH < 7.1 -PAO2/FiO2 <200 mmHg -lactate >5 mmol or >45 mg/L - presence of glucose and ketoacids in urine -continuous use of vasoactive drugs	None	Transfusion ≥3 units of blood
Tanimia 2016 (Papa New Guinea)	None	-pH < 7.1 -PAO2/FiO2 <200 mmHg -lactate >5 mmol or >45 mg/L - presence of glucose and ketoacids in urine -continuous use of vasoactive drugs	None	Transfusion ≥3 units of blood