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Title	Severe maternal morbidity in high income countries
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Publication date	2021
Original Citation	Kaskun, O. (2021) 'Severe maternal morbidity in high income countries', UCC Student Medical Journal, Vol. 2, pp. 1-14. https://doi.org/10.33178/SMJ.2021.1.1
Type of publication	Peer-reviewed Article
Link to publisher's version	https://journals.ucc.ie/index.php/smj/article/view/4313/6473 - 10.33178/SMJ.2021.1.1
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Download date	2026-11-01 09:18:30
Item downloaded from	https://hdl.handle.net/10468/16553

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Severe

Maternal Morbidity

In high income countries

by Oleksandra Kaskun

Reviewed by John Mackrill and Ken O'Hollaran

Abstract

Introduction

With declining maternal mortality rates in high income countries (HICs), severe maternal morbidity (SMM) is becoming an important quality measure of maternal care. However, there is no international consensus on the definition and types of SMM. This study aims to critically analyze published literature on SMM in HICs.

Objectives

To compare definitions and criteria used to identify SMM, and to identify the main types and risk factors contributing to SMM in eight HICs.

Methods

Three databases were searched, results were filtered, and ten studies were critically appraised.

Results

Six of the articles discussed SMM identification criteria and proposed definition modifications. Longer hospital stay and admission to intensive care unit were suggested as additional criteria. Disease-based criteria was shown to be superior to organ dysfunction criteria. Seven articles detailed common types of SMM as severe haemorrhage, hypertensive disorders, and pre-eclampsia/eclampsia. Six articles described SMM risk factors, of which advanced maternal age and caesarean delivery were most common.

Discussion

This literature review identified disease-based criteria and Canadian study criteria as promising measures of SMM. It also identified several types and risk factors of SMM common between HICs. These findings can help physicians identify women at risk of SMM. The study is however limited to eight HICs and ten studies. Further research should aim to investigate how the measures compare with previous sources of criteria, and to discern the association of weight and race risk factors with SMM.

Introduction

Maternal health is an important measure of a country's overall socioeconomic progress.1

As maternal mortality rates have declined precipitously in high income countries (HICs) to the level of becoming rare events, the World Health Organization (WHO) has suggested tracking the incidence of severe maternal morbidity (SMM) (synonymous with maternal near miss) as a quality indicator of obstetric care.[2] The Maternal Morbidity Working Group organised by the WHO defines maternal morbidity as any chronic or acute health condition which can be due to or aggravated by pregnancy or childbirth and has a negative impact on the woman's wellbeing.[1]

In contrast, there is no standardised definition of SMM, and no internationally consistent case identification criteria. SMM is usually described as a "maternal near miss" case, the near death of a woman who survived a complication relating to pregnancy or childbirth or within 42 days of termination of pregnancy[3,4]. The WHO has proposed guidelines in 2011 for identifying maternal near miss cases based on clinical criteria, laboratory markers, and management proxies.[4] They included five potentially life-threatening conditions (severe postpartum haemorrhage, severe pre-eclampsia, eclampsia, sepsis, and ruptured uterus), a range of critical interventions or the admission to intensive care unit, as well as seven types of organ dysfunction as near miss criteria.[4] However, varying definitions of SMM and variations of case inclusion criteria have been used by hospitals and countries around the world. These variations can be the inclusion or exclusion of pre-pregnancy conditions in the definition of maternal morbidity, or suggested expansions to either the 2011 WHO list or other country-specific lists of criteria.[The non-uniformity of the definition and the lack of consensus on inclusion criteria for identifying SMM cases hampers comparative analysis and determination of the true global burden of SMM.

The rates of SMM have not seen similar declines as have maternal mortality rates, and in some HICs such as the USA, they have increased. According to the Centers for Disease Control and Prevention (CDC), the annual prevalence of SMM in the United States (U.S.) has more than doubled between 1998 and 2014.[5] The apparent increase in SMM can be attributed to the changing characteristics of women giving birth over the last few decades – advanced maternal age, obesity, co-morbidities such as diabetes or hypertension, as well as the increased occurrence of caesarean delivery. These factors have been associated with higher SMM risk,[5] but the increase can also be due to changes in SMM identification criteria.

Box 1:
List of Abbreviations

BMI: Body mass index
CCI: Canadian Classification of Health Interventions
CDC: Centers for Disease Control and Prevention
CWIUH: Coombe Women and Infants University Hospital
DIC: Diffuse intravascular coagulation
HICs: High income countries
HDU: high dependency unit
ICD: International Classification of Diseases
ICU: Intensive care unit
KEMH: King Edward Memorial Hospital
SLE: Systemic lupus erythematosus
SMM: Severe maternal morbidity
WHO: World Health Organization

Aims and Objectives

The aim of this study was to systematically analyse and critically appraise published literature on SMM in obstetrics in HICs with the specific objectives as follow:

1. To compare the definitions and criteria used to identify SMM in HICs.
2. To identify the main types of SMM in different countries.
3. To identify the principal risk factors contributing to SMM.

Methods

Search Strategy

An electronic search was performed using three databases, PubMed, Cumulative Index of Nursing and Allied Health Literature (CINAHL), and Scopus, to identify relevant literature to answer the objectives of this review.

PubMed:

1. Severe maternal morbidity:
   "severe maternal morbidity"[text word] OR "Near Miss, Healthcare"[Mesh] OR "maternal near miss"[text word] OR "maternal near-miss"[text word] OR near-miss[text word] OR "near miss"[text word]
   AND
2. High income countries:
   "Developed Countries"[Mesh] OR "high income countr*"[text word] OR "developed countr*"[text word]

Results were filtered for publication in the last 10 years, free full text availability, and availability in English.

CINAHL:

1. Severe maternal morbidity:
   ("severe maternal morbidity" OR "maternal near miss" OR "maternal near-miss" OR near-miss OR "near miss") [all text]
   AND
2. High income countries:
   ("Developed Countr*" OR "high income countr*")[all text]

Results were filtered for publication between 2010 and 2020 inclusive, free full text availability, availability in English, and academic journal type.

Scopus:

1. Severe maternal morbidity:
   ALL ("severe maternal morbidity" OR "maternal near miss" OR "maternal near-miss" OR near-miss OR "near miss")
   AND
2. High income countries:
   ALL ("Developed Countr*" OR "high income countr*")

Results were filtered for publication between 2010-2020 inclusive, free full text availability, availability in English and document type 'Article'. Studies greater than ten years old were excluded to limit the number of results obtained.

Category	Inclusion Criteria	Exclusion Criteria
Publication Date	2010-2020	Prior to 2010
Text Availability	Free full text available	Unavailable free full text
Language	English	Not in English
Article Type	Original research in academic journals	Systematic review Poster/conference Protocol Commentary article Literature Review Case Study Narrative Review
Research Location	Current HICs as defined by World Bank	Not in HICs
Type of pregnancy	Singleton	Twin/multiple
Outcomes	Focused on SMM outcomes or factors	1. Out of scope or not focused on SMM outcomes 2. Focused on maternal mortality outcomes 3. Focused on neonatal outcomes

Table 1:
Inclusion and exclusion criteria for screening of articles by title and abstract.

Table 3:

Reasons for Exclusion	n=
Focus on association of only one factor with SMM	9
Focus on association of socioeconomic factors with SMM	5
Focus on association of ethnic factors with SMM	2
Outcomes not reported in terms of SMM (substandard care or future progress focus)	2
Focus on model validation as outcomes	1
Focus on definitions of SMM criteria instead of which criteria to be included	1
Total Exclude	20

Inclusion and Exclusion Criteria

Table 1 summarizes the inclusion and exclusion criteria for articles to pass the initial screening by title and abstract.

Study Selection

The initial PubMed search yielded 52 results, which was condensed to 24 after filters. CINAHL produced 145 results, 105 after filters. Scopus produced 574 results, 206 after filters. This resulted in 335 papers. Results from the databases were combined using the reference manager Mendeley yielding 288 papers after duplicates were removed. Subsequent results were screened for eligibility by title and abstract according to the inclusion and exclusion criteria in Table 1. The breakdown for reasons 261 papers were excluded from the review are seen in Table 2. The remaining 27 articles underwent a full text review, of which 20 were excluded for the reasons in Table 3. Seven articles were included. To supplement the search, three articles were added from the reference list of the other articles,6-8 totalling ten articles included in the review. The flowchart in Figure 1 illustrates the selection process.

Reasons for Exclusion	n=
Studies out of scope/not focused on SMM outcomes	112
Not in HICs	71
Studies focused on maternal mortality outcomes	26
Studies focused on neonatal outcomes	10
Studies focused on twin/multiple births	2
Protocol	12
Poster/ Conference	9
Systematic Review	7
Literature Review	6
Commentary Article	4
Case Study	1
Narrative Review	1
Total Excluded	261

Table 2:
Reasons for exclusion of articles after screening by title and abstract.

Article Validity

The ten articles selected for this review were critically evaluated using the EBL Critical Appraisal Checklist.17

Results

Summary Tables

From a total of ten studies, there were six retrospective cohort studies [6,7,9,12-14], three prospective cohort studies[8,11,15], and one that had a combined type of first half retrospective and second half prospective cohort.10 The studies were conducted across eight countries, the majority in the USA [3], and one each in Canada[9], Australia[11], Ireland[8], Italy[15], Netherlands[14], United Arab Emirates[10] (this is a HIC according to World Bank). One study12 covered three countries, USA, Australia, and England. The sample sizes ranged from 19 cases of SMM (among 2,773 live births)11 to 47,973 cases of SMM (among 3,556,206 deliveries)[7]. Study periods ranged from six months[8,11] to ten years.[15] A summary of the characteristics of the included studies is presented in Table 4 in the appendix (see Box 1 in Section 2 for abbreviations used in table).

Critical Appraisal

The EBL Critical Appraisal Tool [17] was used to assess bias in studies by evaluating the validity and quality of each study reviewed in an objective and standardised manner (Appendix A). The validity scores are presented in Table 5. All articles have section and overall scores above 75% and thereby were deemed valid.

Study	Population Validity	Data Collection Validity	Study Design Validity	Results Validity	Overall Validity
Dzakpasu S, *et al.* (2020)	100%	100%	100%	100%	100%
Ghazal-Aswad S, *et al.* (2013)	100%	100%	100%	83%	96%
Jayaratnam S, *et al.* (2018)	80%	100%	100%	83%	91%
Lazariu V, *et al.* (2017)	100%	100%	100%	100%	100%
Leonard SA, *et al.* (2019)	100%	100%	100%	100%	100%
Lipkind HS, *et al.* (2019)	100%	100%	100%	83%	96%
Mhyre JM, *et al.* (2011)	100%	100%	100%	100%	100%
O'Malley EG, *et al.* (2016)	80%	100%	100%	83%	91%
Witteveen T, *et al.* (2016)	100%	100%	100%	100%	100%
Zanconato G, *et al.* (2019)	100%	100%	100%	83%	96%

Table 5:
Validity scores calculated using EBL Critical Appraisal Tool

Objective 1: Comparing SMM definitions and criteria

Six of the articles discussed SMM definitions and case criteria.[6,8,9,13-15]To identify SMM cases, two articles from the United States used the International Classification of Diseases 9th edition (ICD-9),[6,13] one Canadian article used both the ICD 10th edition (ICD-10) and the Canadian Classification of Health Interventions (CCI) [9], two European articles used the WHO maternal near miss criteria1[4,15], and one Irish article[8] used the WHO criteria alongside the Scottish Audit criteria.[16] All of these articles either commented on the use of the criteria to identify cases, or attempted to expand on the definitions/criteria of these systems.

Lazariu and colleagues expanded on the ICD-9 criteria for SMM cases by including a long hospital stay (at or above 90th percentile) and admission to the intensive care unit (ICU) as part of the definition.[6] This resulted in a 3% increase in SMM cases compared to using ICD only. Mhyre and colleagues suggested a similar expansion on the ICD-9 definition, by adding end-organ injury with length of stay greater than 99th percentile or discharge to second medical facility.[13] Dzakpasu and colleagues investigated a list of morbidity types and subtypes, their incidence and their association with case fatality and length of hospital stay.[9] They evaluated thirteen SMM types that were not a part of the ICD-10 or CCI, of which six were suggested for inclusion.

O'Malley and colleagues reported double the cases identified as SMM using the Scottish Audit criteria, compared to WHO criteria.[8]

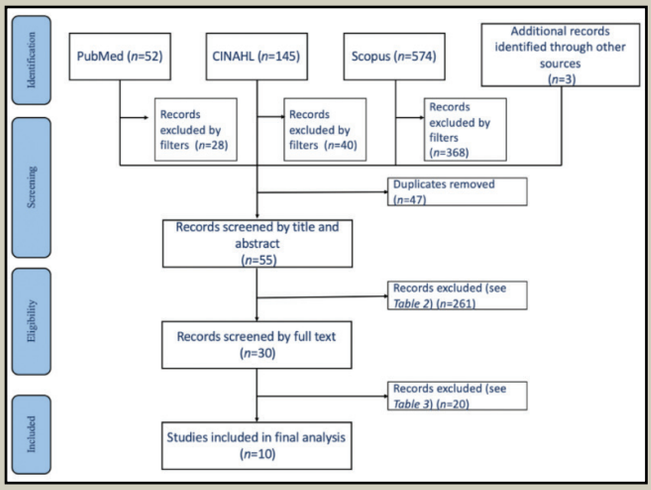

Figure 1:
PRISMA chart outlining article selection process from initial search to final inclusion

Zanconato and colleagues, and Witteveen and colleagues both investigated the 2011 WHO SMM criteria. The former focused on using only the intervention-based and organ dysfunction criteria.15 Meanwhile the latter group used all three WHO criteria categories separately and suggested that disease-based criteria identified the most cases, while organ dysfunction criteria missed about 60 percent of SMM cases.[14]

Objective 2: Main types of SMM

Seven of the articles detailed the main types

of SMM in their respective countries.[8-12,14,15] All but one[12]of these articles reported a severe obstetric haemorrhage as the main type of SMM. The Italian15, Irish8, and United Arab Emirates[10] studies reported haemorrhage and hypertensive disorders as the most common types of SMM. Meanwhile, the Canadian[9] and Dutch[14] studies reported it to be ICU admission. Other types that were common between some studies were pre-eclampsia and/or eclampsia[9,11,12], diffuse intravascular coagulation (DIC)[12,14], and hysterectomy.[9,12]

Objective 3: Principle risk factors of SMM

Six of the articles described risk factors associated with SMM.[6,7,9,12-14] The two most common risk factors were advanced maternal age[6,7,9,12,14] and a caesarean delivery.[6,7,9,15] Advanced maternal age was either defined as above age 35 or 40 depending on the study. Leonard and colleagues reported that SMM was two times higher among women with a caesarean delivery than a vaginal delivery.[7] The study also did not find an association between SMM and pre-pregnancy obesity,[7] while Lazariu and colleagues reported an association between SMM and being underweight instead.[6] Two studies identified maternal comorbidities as a risk factor, which included a variety of conditions such as pulmonary hypertension, chronic renal disease, and malignancy.[7,13] Leonard and colleagues also reported that SMM was two times higher among women with comorbidities.[7] Two studies suggested non-white origin to also be a risk factor.[6,15]

Discussion

This study looked at ten international articles to ascertain criteria used to identify SMM, and to identify the main types of and risk factors contributing to SMM among eight HICs. There is no international consensus on which criteria to use to identify SMM. As seen in the results, the ICD and the WHO are common sources of identification criteria for countries, with two additional sources being the CCI and the Scottish Audit. Two articles with long study periods and large samples suggested to expand the ICD criteria to include longer hospital stay and admission to ICU/secondary medical facility, to more comprehensibly identify SMM cases.[6,13] The Canadian study evaluated the ICD-10, CCI, and new measures to propose a master list of types and subtypes that can be used to identify SMM.[9] They suggested adding the following types of SMM to the ICD-10 list: severe pre-eclampsia, HELLP syndrome, acute fatty liver and red blood cell transfusion, ICU admission, and inversion of uterus.[9] This study had a large, diverse sample allowing external validity, is recent (2019), demonstrates extensive research, clarity, and used a multidisciplinary team to limit bias. According to the WHO, the organ dysfunction criteria are the most promising markers to detect SMM.[14] However, as demonstrated by Witteveen and colleagues (and seen to an extent in O'Malley and colleagues8), these criteria missed 60% of cases, and instead disease-based criteria warrant further attention.[14] Thereby, these findings provide guidance on how to achieve a representative definition of SMM. Specifically, the route of using disease-based criteria, as well as the measures identified by the Canadian study should be used as the basis for future identification of SMM.

As HICs use different criteria to identify SMM cases and consist of a differing composition of individuals, the main types and risk factors of SMM were compared between countries. Much similarity was nevertheless seen between the principal types and risk factors affecting women in the different HICs. This suggests a few common factors that need to be addressed and monitored to limit SMM in the future. The most common types of SMM were severe haemorrhage as identified by six articles[8-11,14,15], hypertensive disorders named by three articles[8,10,15], and pre-eclampsia/eclampsia also by three.[9,11,12] Of these articles, O'Malley and colleagues is of a lower quality mainly due to the small sample size and limitation to the HDU, which

reduces external validity and the ability to draw generalisable conclusions.8 However, it remains in agreement with the other articles on principal types of SMM.
The most common risk factors between countries were advanced maternal age[6,7,9,12,14] and caesarean delivery[6,7,9,15], with two studies also suggesting comorbidities as a factor.[7,13] An issue that arose was the differing definition of advanced maternal age, as it was either above 35 or above 40 years. It is important to establish a consensus for this factor for improved study comparability and clinical case screening. The association of the factors with SMM was identified in previous literature[5,18], with the addition of obesity as a factor. However, Leonard and colleagues did not find this association[7] and being underweight was suggested as a factor instead[6]. The role of pre-pregnancy weight in SMM requires further study. Two studies also suggested race to be a risk factor, specifically non-white origin[6,15]. One study was from New York State[6], using a very large, diverse sample, and the other was Italian[15], using a sample of just over 100 SMM cases at a single institution (lacking external validity). However, racial disparity was also documented in two other studies, which reported increased SMM among non-western immigrant women[19] or sub-Saharan African women[20]. The role of race should also be further investigated as a risk factor, and to determine if this is a consistent finding among various countries or if it is a bias due to the confounding socioeconomic status.

Strengths and Limitations

A strength of this literature review is the inclusion of a variety of international articles representing eight HICs, most of which have large sample sizes, and all of which were critically appraised to be over 90% valid. Furthermore, using three databases provided access to over 700 studies, and the systematic approach allowed reproducibility.
Limitations include being limited to only ten articles and 8 HIC due to word restrictions, only one researcher screened the articles, and inclusion was limited to free full texts in English, as additional studies were of interest but were not accessible. Additionally, two of the included studies, despite having over 90% validity, had small numbers of SMM cases[8,11].

Conclusion

SMM is an important measure of maternal quality of care and yet there is no international consensus on which criteria to use to identify SMM. This literature review sought to bridge this gap and was able to identify disease-based criteria and the Canadian study criteria as promising measures of SMM. Despite the differences in criteria used between HICs, similar principal types of SMM were identified: severe haemorrhage, hypertensive disorders, and pre-eclampsia/eclampsia. Furthermore, common risk factors were also identified among the countries (advanced maternal age and caesarean delivery) that can assist with screening and identifying potential cases at risk of SMM. A consensus on defining SMM should be reached to allow obstetricians to identify patients that are at risk of SMM and to practice improved preventative medicine.

Future Investigations

As disease-based criteria and the Canadian study criteria seem to provide a more comprehensive insight into SMM than other methods. These measures should be further studied in other HICs to determine how they compare with previous sources of criteria. Additionally, future investigation into the association of risk factors with SMM, particularly weight and race, is required to improve early screening for SMM cases.

Acknowledgements

I would like to acknowledge the literature review supervisor Dr Richard Greene, from the Obstetrics and Gynaecology department at Cork University Maternity Hospital.

Appendix A

EBL Critical Appraisal Checklist[17]		Dzakpasu S, *et al.* (2020)	Ghazal-Aswad S, *et al.* (2013)	Jayaratnam S, *et al.* (2018)	Lazariu V, *et al.* (2017)	Leonard SA, *et al.* (2019)	Lipkind HS, *et al.* (2019)	Mhyre JM, *et al.* (2011)	O'Malley EG, *et al.* (2016)	Witteveen T, *et al.* (2016)	Zanconato G, *et al.* (2019)
Section A: Population	Is the study population representative of all users who might be included in the study?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Are inclusion and exclusion criteria clearly outlined?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Is the sample size large enough to obtain precise estimates?	Y	Y	N	Y	Y	Y	Y	N	Y	Y
	Is the response rate sufficient for precise estimates?	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Is the choice of population free from bias?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	If a comparative study: Were participants randomized?	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	At baseline, were the groups comparable?	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	If not, was this addressed in the analysis?	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Was there informed consent?	N/A	Y	Y	N/A	N/A	N/A	N/A	Y	Y	Y
Section B: Data Collection	Are data collection methods reported clearly?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	If a face-to-face survey, were inter-observer and intra-observer bias reduced?	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Is the data collection instrument validated?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	If based on commonly obtained statistics, are they free from subjectivity?	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Is the outcome measured at an appropriate time for reporting the intervention's effect?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Is the instrument included in the publication?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Are questions presented sufficiently clear in order to obtain accurate answers?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Were those involved in data collection not involved in supplying a service to the target population?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Section C: Study Design	Is the study type / methodology operated appropriate?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Is there face validity?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Is the research methodology precisely reported at a level that would permit its replication?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Was ethical approval granted?	N/A	Y	Y	N/A	N/A	N/A	N/A	Y	Y	Y
	Are the outcomes clearly reported and discussed regarding the data collection?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Section D: Results	Are all the results clearly reported?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Are confounding variables accounted for?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Do the conclusions reflect the analysis accurately?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Is subset analysis a minor, rather than a major, focus of the article?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Are suggestions provided for further areas to research?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Is the study externally valid?	Y	N	N	Y	Y	U	Y	N	Y	N

Legend: Yes (Y), No (N), Unclear (U), Not Applicable (N/A); Y/Total = %

Appendix B

Author (Year), Location, *Title*	Objectives	Study Type, Study population, Sample size	Study Methodology	Key Findings	Strengths & Limitations	Future Research
Dzakpasu S, *et al.* (2020) Canada (Excluding Quebec) *Severe maternal morbidity surveillance: Monitoring pregnant women at high risk for prolonged hospitalisation and death.* (9)	1. To propose a comprehensive definition of SMM 2. To create an empirically justified list of SMM types and subtypes 3. To use information in 1 & 2 to examine SMM in Canada.	Retrospective cohort All hospital deliveries in Canada (excluding Quebec) between 2012 and 2016 n = 22,799 cases of SMM (among 1,418,545 deliveries)	Discharge Abstract Database of the Canadian Institute for Health Information was used to obtain: • maternal/infant characteristics • labour & delivery • diagnoses & procedures SMM cases were identified using ICD-10 and CCI Potential SMM types and subtypes were evaluated by examining rates, temporal trends, length of hospital stay, and case fatality rates for 2006-2015. The list of SMM was then used to describe SMM in Canada for 2012-2016.	1. SMM rate was 16.1/1000 deliveries 2. Main types of SMM were severe pre-eclampsia and HELLP syndrome, severe postpartum haemorrhage, maternal ICU admission, and hysterectomy. 3. SMM rate was higher in older women (>40yo), and previous or current caesarean delivery. 4. Twelve SMM types were identified and 46 subtypes.	Strengths: • Very large sample size • Included ~98% of all deliveries in Canada • Multidisciplinary input and evidentiary support from contemporary data • The hospitalisation data source has made coding changes to facilitate comprehensive monitoring • Proposed new criteria for SMM • Long study period Limitations: • Inability to identify some clinically relevant cases due to data source coding (severe obesity) and to distinguish between pre-existing and acute complications • Exclusion of Quebec	To include Quebec, and use a more detailed data source which can monitor a wider range of case types
Ghazal-Aswad S, *et al.* (2013) United Arab Emirates (Abu Dhabi emirate) *Severe Acute Maternal Morbidity in a High-Income Developing Multiethnic Country.* (10)	To study the epidemiology of SMM in a HIC.	Retrospective cohort first 3 years and prospective cohort last 3 years All births occurring in maternal units with over 500 births/year (4 units) in the Emirate of Abu Dhabi between 1998 and 2003. n = 926 cases of SMM (among 122,705 deliveries)	Clinical criteria consisting of eight conditions were used to identify SMM cases. First 3 years, cases obtained from hospital records. Last 3 years, cases obtained using form with relevant clinical data.	1. SMM rate was 7.5/1000 deliveries 2. The most common types of SMM were hypertensive disorders and haemorrhage.	Strengths: • Long study period • Prospective design portion • Clinical criteria was clearly defined Limitations: • Old dataset • Only one province was included and limited to large maternity units	Inclusion of a wider range of clinical, intervention, and disease-based criteria to identify SMM cases.
Jayaratnam S, *et al.* (2018) Australia *Maternal 'near miss' collection at an Australian tertiary maternity hospital.* (11)	To determine the rate and aetiology of maternal near misses at KEMH using WHO near miss criteria.	Prospective observational All women admitted to KEMH between December 1 2014 and May 31 2015 during pregnancy or within 42 days of its termination n = 19 cases of SMM (among 2,773 live births)	A form with clinical and biochemical parameters was used to identify potential cases based on WHO criteria of near misses Cases were identified and collected daily; a structured form was then completed when case was confirmed to be SMM (including age, length of hospital stay)	1. SMM rate was 7/1000 deliveries 2. Main types of SMM were post-partum haemorrhage, pre-eclampsia, and early pregnancy complications.	Strengths: • Cases were reviewed independently by two investigators • Prospective design Limitations: • Small sample • Only one hospital; not nationally representative • Short study period	Developing software that can automatically identify near miss cases using routinely collected information Longer study period Expanding to multiple hospitals across the country
Lazariu V, *et al.* (2017) United States (New York) *Severe maternal morbidity: A population based study of an expanded measure and associated factors.* (6)	1. To evaluate the impact of expanding the CDC measures of SMM to include pre-existing conditions and ICU admission. 2. To identify risk factors associated with SMM.	Retrospective population-based observational study All New York State female residents, 10-55yo, who had live births at New York acute care hospitals between 2008 and 2013 inclusive n = 34,478 cases of SMM (among 1,352,600 hospital deliveries)	Information was collected from administrative database records (hospital discharge, vital records) SMM cases were identified using the 9th edition of ICD (ICD-9 CM), with the addition of long hospital stay (at or above 90th percentile) and admission to ICU.	1. Case incidence of 2.55% (25.5/1000) using the expanded criteria (3% increase in cases compared to using ICD only) 2. Risk factors for SMM were identified as age<20 or >35, underweight, caesarean delivery, non-white race.	Strengths: • Very large sample size (including 93% of live birth records for New York State) • Expanded the ICD definition of SMM • Long study period Limitations: • Hospital discharge records were used, not all complete, and accuracy can vary by hospital • Pre-pregnancy comorbidities were not recorded consistently in database	Can expand the study to other States Further research into pre-pregnancy comorbidity

Author (Year), Location, *Title*	Objectives	Study Type, Study population, Sample size	Study Methodology	Key Findings	Strengths & Limitations	Future Research
Leonard SA, *et al.* (2019) United States (California) *The contribution of maternal characteristics and cesarean delivery to an increasing trend of severe maternal morbidity.* (7)	To evaluate the association of advanced maternal age (≥35yo), pre-pregnancy obesity BMI ≥30kg/m^2), pre-pregnancy comorbidities, and caesarean delivery with SMM.	Retrospective population-based cohort study Live births in California between January 1 2007 and December 31 2014, with gestation >20 weeks n = 47,973 cases of SMM (among 3,556,206 deliveries)	Used linked birth record and patient discharge data from live births SMM cases were identified using the ICD-9-CM Multivariable logistic regression model used to assess association	1. SMM rate was 13.5/1000 deliveries 2. Pre-pregnancy comorbidities and caesarean delivery were associated with SMM (two-fold higher), advanced age was associated to a lesser degree, but pre-pregnancy obesity was not associate.	Strengths: • Very large, diverse sample size • Linkage between vital records and patient records allowed the study of pre-pregnancy risk factors • Long study period Limitations: • Observational study • Data may lead to misclassification (pre-pregnancy weight was self-reported) • Limited to California • Included limited number of risk factors	Expand to other States Include additional risk factors
Lipkind HS, *et al.* (2019) USA, Australia, England *Severe maternal morbidity during delivery hospitalisation in a large international administrative database, 2008–2013: a retrospective cohort.* (12)	To identify pregnancy complications and associated risk factors leading to SMM	Retrospective cohort Delivery hospitalisations in large university hospitals in USA, Australia and England between 2008 and 2013 n = 4,333 cases of SMM (among 516,781 deliveries across 18 hospitals)	Dr. Foster Global Comparators Database was used to identify delivery hospitalisations with life-threatening diagnoses or use of life-saving procedures SMM cases were identified using the ICD-10 in England and Australia and ICD-9 CM in the USA Frequency per country was calculated.	1. Overall SMM rate was 8.2/1000 deliveries: • 15.6 in USA • 8.2 in Australia • 5.0 in England 2. Most common types of SMM were DIC, acute renal failure, cardiac events ventilation, hysterectomy, and eclampsia. 3. Risk factors associated with SMM were advanced maternal age (>40yo), hypertension, diabetes, and substance abuse.	Strengths: • Large, international sample size • Use of academic medical centres for consistency • Long study period Limitations: • Data relies on hospital discharge coding, which can vary between countries and hospitals • Limited number of hospitals are represented, with more than half (57%) from England – countries are not equally represented • May not be representative of country as only academic centres included	Inclusion of more hospitals across the countries for better generalization Equal representation of countries to improve comparability
Mhyre JM, *et al.* (2011) United States *Influence of Patient Comorbidities on the Risk of Near-miss Maternal Morbidity or Mortality.* (13)	To determine the extent to which it is possible to predict which patients will experience SMM (to identify risk factors for SMM).	Retrospective cohort Maternal hospital admissions for delivery in the Nationwide Inpatient Sample (NIS) between 2003 and 2006 n = 4,550 cases of SMM (among 3,463,327 deliveries)	NIS dataset was used (which is a 20% stratified sample with ~1000 hospitals) SMM cases were identified using ICD-9-CM	1. Defined SMM (in addition to ICD measures) as end-organ injury with length of stay greater than 99th percentile or discharge to second medical facility. 2. SMM rate was 1.3/1000 deliveries 3. The risk factors contributing to majority of SMM were comorbidities (pulmonary hypertension, malignancy, SLE) and complications (DIC, acute liver disease, acute respiratory distress syndrome).	Strengths: • Large, diverse, national sample size • Expanded on the ICD-9 definition of SMM • Access to pre-existing comorbidity data Limitations: • Specific ICD codes do not exist for many conditions (placenta accreta), so they could not be studied • NIS does not have enough sample size to study rare conditions • Old dataset	Investigate hospital-level variation in SMM Investigate the impact of using other measures (besides ICD-9) to identify SMM cases on sample
O'Malley EG, *et al.* (2016) Ireland *Maternal near miss: what lies beneath?* (8)	1. To determine incidence and common reasons for admission to high dependency unit (HDU) 2. To determine categories (types) of SMM	Prospective cohort All women admitted to the Coombe Women and Infants University Hospital (CWIUH) HDU from May 5 to November 5 2014 n = 128 admissions to HDU (among 4,502 live births)	Study population was identified prospectively and data was recorded including demographics, admission reason, length of stay, interventions, ICU transfer, and outcomes. Scottish Audit and WHO criteria were used to identify SMM cases Sample was divided into three groups: 1) near miss cases 2) severe maternal complications but no organ dysfunction 3) not SMM	1. Of the 128 admissions to HDU, 16 women fulfilled SMM criteria defined by the Scottish Audit, while 8 met the WHO criteria; 83 women with severe maternal complications. 2. Common reasons for admission to HDU were haemorrhage, hypertension, and sepsis.	Strengths: • Used two different SMM criteria to identify cases (Scottish Audit and WHO) • More recent dataset Limitations: • Short study period • Small sample number (16+8 cases meeting criteria) • Limited to HDU admissions; may be missing cases of SMM	Expand study to other hospitals in the country for better representation Increase study period to obtain greater sample size

Author (Year), Location, *Title*	Objectives	Study Type, Study population, Sample size	Study Methodology	Key Findings	Strengths & Limitations	Future Research
Witteveen T, *et al.* (2016) Netherlands *Validating the WHO Maternal Near Miss Tool in a high-income country.* (14)	1. To investigate the applicability of the WHO maternal near miss tool (MNM tool) in Netherlands. 2. To determine if organ dysfunction criteria (from MNM tool) are suitable markers of SMM.	Retrospective cohort Women with SMM in Netherlands between August 1, 2004 and August 1 2006. n = 2,552 cases of SMM (among 371,623 deliveries)	MNM tool was applied to data collected in a previous prospective study (LEMMoN study)	1. About 9% of cases identified as SMM in the LEMMoN study were missed using the WHO criteria. 2. Organ dysfunction criteria failed to identify ~60% of SMM cases. Disease-based criteria detected ~90% of SMM cases. 3. The most common types of SMM were postpartum haemorrhage, DIC, and admission to ICU. 4. Risk factors associated with SMM were identified as higher maternal age (35+) and long hospital stay.	Strengths: • Two independent investigators applied MNM tool to cases and discrepancies were discussed with team • Large sample size Limitations: • Used data from previous study that identified cases based on other criteria • Incomplete or missing information in the database (bias limited by team discussion) • Older dataset	Applying MNM tool on more recent dataset, with an emphasis on disease-based criteria as opposed to organ dysfunction criteria
Zanconato G, *et al.* (2019) Italy *Perinatal outcome of severe obstetric complications: findings of a 10-year hospital-based surveillance study in Italy.* (15)	To determine the incidence and clinical patterns of SMM in Italy.	Observational prospective study Women admitted to the University Hospital of Verona between January 2007 and December 2016 n = 151 cases of SMM (among 17,560 deliveries)	Medical records in the obstetric ward and ICU provided the data which was entered into an Access database SMM cases were identified using the 2011 WHO criteria (specifically the intervention-based and organ dysfunction criteria)	1. SMM incidence rate was 8.6/1000 deliveries 2. The most common types of SMM were severe obstetric haemorrhage and hypertensive disorders. 3. Factors also associated with SMM were pre-term birth, caesarean section, and sub-Saharan African origin.	Strengths: • Long study period • Prospective design Limitations: • Single institution • Only intervention-based and organ dysfunction criteria were used to identify cases; may be missing SMM cases	Include disease-based WHO criteria to identify SMM cases.

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