Maternal Mortality in the United States: A Literature Review

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A Literature Review

AUTHORS Dana Glei, PhD
Magali Barbieri, PhD
University of California, Berkeley

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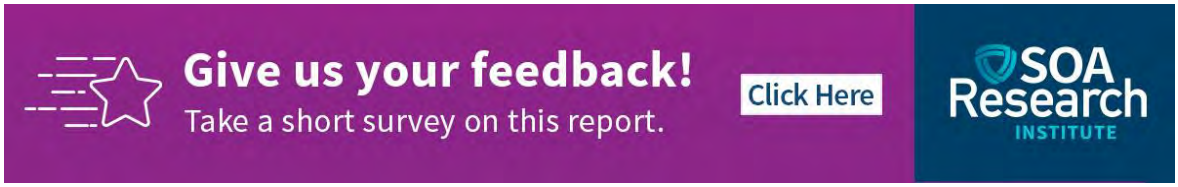

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Maternal Mortality in the United States

A Literature Review

In the U.S. in 2021, there were 32.9 maternal deaths per 100,000 live births.[1] In comparison with other developed countries of similar wealth, the U.S. stands out as having one of the highest maternal mortality rates.[2]

Three years ago, the Society of Actuaries Research Institute's Mortality and Longevity Strategic Research Program Steering Committee (MLPSC), initiated a study to educate actuaries and others on maternal mortality trends and other relevant information to help enhance current mortality modeling. This research was under development prior to the 2022 U.S. Supreme Court decision overturning Roe v Wade.

A formal request to elicit proposals from prospective researchers was issued in 2021. The request instructed researchers to incorporate findings of the study (a literature review and data analysis) into a report to be made available on the Society of Actuaries Research Institute Website. The report would include at a minimum:

- Identification and quantification of U.S. maternal mortality metrics and how the metrics have changed over time.
- Statistically significant differences in maternal mortality by risk factor.
- Impact of U.S. maternal mortality on overall U.S. mortality.
- Comparison of U.S. maternal mortality to other developed countries.

Dr. Magali Barbieri submitted a proposal and the research team was selected by the MLPSC to perform the study. This report is the outcome of the team's work. In addressing the project objectives, some sensitive topic areas found in the literature are mentioned in the paper. The views presented are from the original sources and do not represent the views of the authors, the Society of Actuaries Research Institute, nor the Society of Actuaries.

Executive Summary

The purpose of this report is to review past studies on maternal mortality levels, trends and differentials in the U.S. in a context of rising rates and a recent change in data collection. A secondary goal is to identify remaining gaps in knowledge and the statistical information available for their investigation.

Maternal mortality in the U.S. is comparatively high and exhibits large geographic, racial/ethnic and socioeconomic disparities. After a secular decline throughout much of the 20th century, maternal mortality appears to have increased in the U.S. since the 1990s whereas it has continued to fall in other high-income

[1] Hoyert DL. Maternal mortality rates in the United States, 2021. NCHS Health E-Stats. 2023. DOI: https://dx.doi.org/10.15620/cdc:124678. https://www.cdc.gov/nchs/data/hestat/maternal-mortality/2021/maternal-mortality-rates-2021.pdf

[2] Tikannen, Roosa and et.al. Maternal Mortality and Mortality Care in the U.S. Compared to 10 Other Developed Countries. The Commonwealth Fund. 2020. https://www.commonwealthfund.org/publications/issue-briefs/2020/nov/maternal-mortality-maternity-care-us-compared-10-countries

countries. Part, but not all, of the increase has been attributed to measurement issues, including changes in the International Classification of Diseases and in the format of the death certificate.

The high level of maternal mortality affects most specifically non-Hispanic Black/African American and Native American/Indigenous Resident/Native North American women, whose risks of dying in childbirth are 2.5 to 3 times higher than those of non-Hispanic/Latina white and Hispanic/Latina women. Though low-income women and those with low level of education are more likely to die from a maternal cause than others, racial and ethnic variations in maternal mortality remains even after controlling for income and education. Women living in rural areas and those in the South are particularly at risk. Differential access and quality of prenatal and delivery care and the broader issue of poverty and structural racism have been identified as the root causes of the observed disparities.

Although in the 1980s and 1990s the main medical causes of pregnancy-related deaths were hemorrhage and hypertensive disorders, the leading causes of such deaths have become related to cardiovascular conditions. The changes in the structure of maternal deaths by cause have been explained by increasing maternal age, the higher prevalence of caesarean-section deliveries, the rise in the prevalence of underlying health factors (especially obesity, diabetes and hypertension) and the increasing share of twin pregnancies associated with hormonal stimulation.

Specific policies and interventions are under way to address the problem of high maternal mortality in the U.S., centering on the diffusion of the maternal safety bundle, generalizing standards of maternal care, efforts to expand access to care and improvements in maternal health care and patients' communication. These new programs will need to be evaluated in the future to assess whether the U.S. is successful at reducing the number of maternal deaths, half to two-thirds of which are considered as preventable.

Motivation

Maternal mortality in the U.S. is higher than in other high-income countries and the gap has grown since 1990 as the rates have increased in the U.S. while declining elsewhere (Fleszar et al. 2023). According to the World Health Organization (WHO), the number of maternal deaths per 100,000 births (i.e., maternal mortality ratio or MMR) in 2017 was 19 in the U.S. compared with 14 in eastern Europe, 10 in Canada, 7 in western Europe, 6 in Australia, 6 in northern Europe, 5 in Japan and 4 in southern Europe (2019, Annexes 16 and 17). It is unclear the extent to which the trends and differentials are real and how much may owe to differences in the methodology for identifying maternal deaths (Creanga 2018).

Maternal mortality in the U.S. also exhibits large disparities by race/ethnicity, socioeconomic status (SES) and geography. For example, in 2020, the maternal mortality ratio (the number of maternal deaths per 100,000 births) for non-Latina Black/African American women was 2.9 times that of non-Latina whites and more than 3 times that of Latinas (Hoyert 2022).

Here we provide a critical survey of the scientific literature on maternal mortality trends and differentials and their determinants in the U.S. Particular attention is given to the value of each specific study in light of the recent reclassification of maternal deaths by the National Center for Health Statistics (NCHS).

Methodology Used to Compile the Bibliography

We focus our literature review on studies published in the past 10 years. Among those studies, we identify the 84 most consequential studies and summarize those findings. The 84 references used for this report are presented in the References section. In addition, we have compiled a complete list of references about maternal mortality that is presented in Appendix A. The complete list is organized by topic. Note that some of the publications appear under several different sections of the reference list when they are relevant to more than one topic.

The literature search was conducted using the following list of keywords:

- Maternal mortality in the U.S.
- Maternal death in the U.S.
- Pregnancy-related mortality in the U.S.
- Pregnancy-related deaths in the U.S.
- Maternal mortality rate in the U.S.
- Maternal mortality ratio in the U.S.

We primarily used Google Scholar supplemented by PubMed and help from the University of California, Berkeley, library and documentation services to identify an initial set of relevant publications. We investigated the use of other bibliographic software but found no additional value in addition to the combined reliance on Google Scholar and PubMed. As we reviewed the initial set of publications, we also employed a snowballing approach. Snowballing in this context consists of identifying key publications from the references cited by the most relevant.

As a general rule, we did not include journal editorials, viewpoints, commentaries, letters and master's theses. We also excluded from our analysis publications that were overly general or too clinically oriented. However, we included the latter into a separate section of the organized list of references (Appendix A).

Measurement and Data Quality Issues

DEFINITIONS

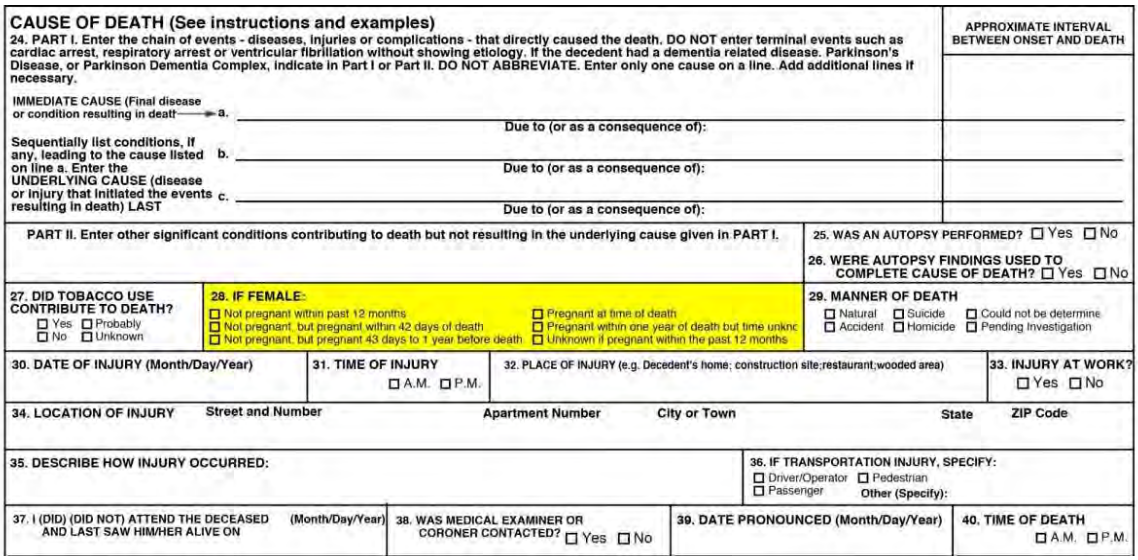
MATERNAL DEATHS

The WHO defines a maternal death as “the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management, but not from accidental or incidental causes” (World Health Organization 2019). Some experts argue that this definition may be insufficient because it provides no formal definition for determining whether a death is “incidental” (Chinn et al. 2020).

The National Center for Health Statistics (NCHS), which is in charge of centralizing and coding causes of death on all death certificates in the U.S., follows the WHO definition of maternal death, but until recently, it was impossible to determine the exact number of maternal deaths in the U.S. according to this definition because of the lack of detailed information on the U.S. death certificate. In particular, the U.S. death certificate did not include any information on whether a woman was, or had been recently, pregnant at the time of her death. NCHS has acknowledged problems with the data collection system and the quality of reporting on maternal deaths. To address these limitations, NCHS introduced a new standard death certificate in 2003, which now includes a checkbox specifically identifying women who were pregnant at the time of death or had been pregnant within 42 days and within one year prior to death. The new certificate was only progressively implemented across the U.S. states, and as a result, gradual improvement in reporting led to an increase in the number of maternal deaths identified in the vital statistics system between 2003 and 2017.

Figure 1

THE 2003 STANDARD U.S. DEATH CERTIFICATE CAUSE-OF-DEATH SECTION WITH THE PREGNANCY CHECK BOX



CAUSE OF DEATH (See instructions and examples)

24. PART I. Enter the chain of events - diseases, injuries or complications - that directly caused the death. DO NOT enter terminal events such as cardiac arrest, respiratory arrest or ventricular fibrillation without showing etiology. If the decedent had a dementia related disease. Parkinson's Disease, or Parkinson Dementia Complex, indicate in Part I or Part II. DO NOT ABBREVIATE. Enter only one cause on a line. Add additional lines if necessary.

APPROXIMATE INTERVAL BETWEEN ONSET AND DEATH

IMMEDIATE CAUSE (Final disease or condition resulting in death) → a. _____ Due to (or as a consequence of):

Sequentially list conditions, if any, leading to the cause listed on line a. Enter the UNDERLYING CAUSE (disease or injury that initiated the events resulting in death) LAST

b. _____ Due to (or as a consequence of):

c. _____ Due to (or as a consequence of):

PART II. Enter other significant conditions contributing to death but not resulting in the underlying cause given in PART I.

25. WAS AN AUTOPSY PERFORMED? ☐ Yes ☐ No

26. WERE AUTOPSY FINDINGS USED TO COMPLETE CAUSE OF DEATH? ☐ Yes ☐ No

27. DID TOBACCO USE CONTRIBUTE TO DEATH? ☐ Yes ☐ Probably ☐ No ☐ Unknown

28. IF FEMALE:
☐ Not pregnant within past 12 months
☐ Not pregnant, but pregnant within 42 days of death
☐ Not pregnant, but pregnant 43 days to 1 year before death
☐ Pregnant at time of death
☐ Pregnant within one year of death but time unknc
☐ Unknown if pregnant within the past 12 months

29. MANNER OF DEATH
☐ Natural ☐ Suicide ☐ Could not be determine
☐ Accident ☐ Homicide ☐ Pending Investigation

30. DATE OF INJURY (Month/Day/Year)

31. TIME OF INJURY ☐ A.M. ☐ P.M.

32. PLACE OF INJURY (e.g. Decedent's home; construction site;restaurant;wooded area)

33. INJURY AT WORK? ☐ Yes ☐ No

34. LOCATION OF INJURY Street and Number Apartment Number City or Town State ZIP Code

35. DESCRIBE HOW INJURY OCCURRED:

36. IF TRANSPORTATION INJURY, SPECIFY:
☐ Driver/Operator ☐ Pedestrian
☐ Passenger Other (Specify):

37. I (DID) (DID NOT) ATTEND THE DECEASED AND LAST SAW HIM/HER ALIVE ON (Month/Day/Year)

38. WAS MEDICAL EXAMINER OR CORONER CONTACTED? ☐ Yes ☐ No

39. DATE PRONOUNCED (Month/Day/Year)

40. TIME OF DEATH ☐ A.M. ☐ P.M.

LATE MATERNAL DEATHS

The definition of a late maternal death is "the death of a woman from direct or indirect obstetric causes, more than 42 days but less than one year after termination of pregnancy" (World Health Organization 2022). Thus, it is essentially the same as maternal death except it includes only those deaths that occur 43 days to one year after the end of pregnancy.

PREGNANCY-RELATED DEATHS

The term "pregnancy-related deaths" combines both maternal and late maternal deaths. It is defined as "the death of a woman while pregnant or within 1 year of pregnancy termination—regardless of the duration or site of the pregnancy—from any cause related to or aggravated by the pregnancy or its management, but not from accidental or incidental causes" (Rossen et al. 2020). Early (within 42 days of pregnancy) and late (within 12 months of termination of pregnancy) pregnancy-related deaths are sometimes distinguished as is the case for maternal deaths.

PREGNANCY-ASSOCIATED DEATHS

Finally, pregnancy-associated deaths encompasses a broader category: "all deaths during pregnancy or within 1 year of pregnancy, regardless of cause" (Rossen et al. 2020). That is, it includes not only deaths that are directly or indirectly related to pregnancy, but also deaths from incidental causes. For example, it includes deaths from homicide, suicide and drug-related overdose, none of which are classified as a pregnancy-related death.

INDICATORS

Multiple indicators measure maternal mortality. The indicators vary in terms of both the numerator (maternal deaths versus pregnancy-related or pregnancy-associated deaths) and the denominator (live births, women of reproductive age, all-cause deaths of women of reproductive age) and whether they take the cumulative effect of fertility into account. The most commonly used indicators are the following:

- The maternal mortality ratio (MMR), which is the ratio of the number of maternal deaths to the number of live births in a given year (usually provided for 100,000 live births)
- The maternal mortality rate, which is the ratio of the number of maternal deaths to the number of women of reproductive age, 15 to 49 years (usually provided per 1,000 women); a variant of this is the rarely used Maternal Mortality Incidence Rate (Riffe 2011)
- The proportion of maternal deaths, which is the ratio of the number of maternal deaths to all deaths (from any cause) of women of reproductive age
- The lifetime risk of maternal death, a little bit more complicated to calculate and with two different measurement approaches: 1) the product of the maternal mortality rate by the number of years of life between the age of 15 and 50 in the appropriate female lifetable, and 2) the sum of the product of the maternal mortality ratio in each age group and the fertility rate in the corresponding age group.

Similar indicators are calculated substituting the number of pregnancy-related, or the number of pregnancy-associated, deaths for the number of maternal deaths in the numerator.

DIFFERENT SYSTEMS FOR MONITORING PREGNANCY-RELATED MORTALITY IN THE U.S.

Three major systems are used for surveillance of maternal mortality in the U.S. These systems have been described in detail by St. Pierre et al. (2018). Here we briefly review the main differences.

NATIONAL VITAL STATISTICS SYSTEM (NVSS)

The National Vital Statistics System (NVSS) is the official source of maternal mortality data for the U.S. The main measure is maternal deaths (i.e., during pregnancy or within 42 days after the end of pregnancy). Classification relies solely on information from the death certificate and is based on International Classification of Diseases (ICD) codes. NVSS provides national trends and forms the basis for international comparisons. The strengths are that NVSS provides the longest historical series, starting in 1900, and the data are publicly available. The main weakness is the lack of detail: the information available from the death certificate and ICD codes is limited. The data are not sufficiently detailed to inform prevention strategies.

MATERNAL MORTALITY REVIEW COMMITTEES

Formation of Maternal Mortality Review Committees (MMRCs) at the state and local level began in the 1930s; by 1968, 44 states and the District of Columbia had active MMRCs (St. Pierre et al. 2018). However, in the late 1980s, nearly half of MMRCs disbanded because of a decline in maternal deaths and fear of litigation, though some have since reopened so that about two-thirds of the states had a MMRC in 2019 (Collier and Molina 2019; Weigel 2019).

Unlike NVSS, the main measure is pregnancy-related deaths (i.e., during pregnancy or within *one year* after the end of pregnancy). Multidisciplinary committees classify deaths, starting with a list of suspected deaths from NVSS and using a range of information that include prenatal and hospital records as well as autopsy reports (Zaharatos et al. 2018). The MMRC investigates those deaths in detail to determine the causes, contributing factors and whether they may have been preventable (MacDorman, Declercq and Thoma 2018).

The purpose of the MMRC is to identify, review and analyze maternal deaths using all available data to understand medical and nonmedical contributors to deaths, to determine which maternal deaths might have been prevented, and to make recommendations to address such deaths (Creanga 2018; St. Pierre et al. 2018). State MMRC data are considered the gold standard (Creanga 2018; Collier and Molina 2019). The strengths are that MMRCs provide more accurate identification and comprehensive review of deaths and allow specific recommendations for prevention informed by local context. The weaknesses are that MMRCs are very resource-intensive, requiring data from multiple sources and review by multiple stakeholders; variation in processes across jurisdictions inhibit use for national surveillance because of the lack of comparability; and the data are not publicly available.

PREGNANCY MORTALITY SURVEILLANCE SYSTEM

The Pregnancy Mortality Surveillance System (PMSS) was developed in 1986 in response to the declining number of MMRCs and the limited accuracy of death certificate data reported by NCHS (Weigel 2019; Centers for Disease Control and Prevention 2020). Like the MMRCs but unlike NVSS, the main measure is pregnancy-related deaths. Deaths are classified by medical epidemiologists using Provision of Medical Services Statement (PMSS) codes (St. Pierre et al. 2018). De-identified copies of death certificates for women age 12–55 who died during or within one year of pregnancy are linked with birth/fetal death

certificates and then reviewed by specially trained clinicians who determine whether or not the death was pregnancy-related (MacDorman, Declercq and Thoma 2018).

The main purpose of the PMSS is to analyze clinical factors associated with deaths and publish information that may lead to prevention (St. Pierre et al. 2018). Creanga (2018, p. 298) notes that PMSS includes "considerably more nuanced clinical and epidemiological data" than NVSS. The strength is that PMSS represents the most clinically relevant national measure of the burden of maternal deaths (St. Pierre et al. 2018). Its weaknesses include that information is primarily limited to the data available from death and birth certificates, they do not capture detailed information on the contributors to deaths, and the data are not publicly available.

METHODOLOGICAL ISSUES REGARDING THE MEASUREMENT OF MATERNAL MORTALITY

Earlier research suggested that maternal mortality was underestimated by the NVSS (Creanga 2018; Hoyert, Uddin and Miniño 2020). Linking deaths of women with either birth or fetal death records improves identification; most states perform such linkages before reporting data to PMSS or their state's MMRC, but not before reporting mortality statistics to NVSS (Creanga 2018). MacDorman, Declercq and Thoma (2018) argue that MMRCs spend too much time eliminating false positives because of inaccuracies in the count of maternal deaths provided by NVSS. One challenge for identifying maternal deaths is that recent or current pregnancy may not be recorded (Joseph et al. 2017). The comparability of data across the U.S. is also constrained by variation across hospitals and geographic areas in who is assigned to record deaths and how maternal deaths are coded (Chinn et al. 2020).

In an effort to improve the identification of maternal deaths, some states introduced pregnancy status indicators on their death certificate,[3] but the format varied across states (Hoyert, Uddin and Miniño 2020). As previously mentioned, the U.S. Standard Certificate of Death added a pregnancy question in the form of a checkbox item in 2003 (Hoyert, Uddin and Miniño 2020). States were urged to adopt this standard pregnancy checkbox, but the timing of implementation in different states was staggered over 14 years. West Virginia was the last state to add a pregnancy checkbox in mid-2017 (Hoyert, Uddin and Miniño 2020). As a result of the staggered implementation of the pregnancy checkbox, the comparability of data across states diverged over time. Consequently, NCHS suspended publication of national mortality statistics for more than a decade—from 2007 to 2018. Publication of maternal mortality statistics for the U.S. resumed in 2020 with the release of data for 2018. By 2018, all 50 states included a pregnancy checkbox on the death certificate, although the pregnancy checkbox used in California remains inconsistent with the standard (Hoyert and Miniño 2020). Because of the nonstandard checkbox (the death certificate identifies maternal deaths with a question about pregnancy within the year of death but without any additional information on the timing of death with respect to pregnancy), California is likely to underestimate maternal deaths and overestimate late maternal deaths (Hoyert, Uddin and Miniño 2020).

As expected, the addition of the new checkbox increased the identification of maternal deaths (MacKay et al. 2000). For example, analyses suggested that in 2015–16 use of a pregnancy checkbox more than tripled the number of maternal deaths but resulted in a 40-fold increase in the number of late maternal deaths (Hoyert, Uddin and Miniño 2020).[4] The effect of the checkbox was especially large for women aged 40 and

[3] In 1991–92, 16 states and New York City already included a checkbox or question about pregnancy status of the decedent (MacKay et al. 2000).

[4] Three states were excluded from the analyses of the effect of the pregnancy checkbox in 2015–16 (Hoyert, Uddin and Miniño 2020): California (because it still uses a nonstandard checkbox); West Virginia (because it did not add the checkbox until 2017); and Alabama (because it did not add the checkbox until 2016).

older (Rossen et al. 2020); The addition of the checkbox resulted in a 14-fold increase in the number of maternal deaths among women aged 40–54 (Hoyert, Uddin and Miniño 2020).

Although the checkbox yielded greater sensitivity in detecting maternal deaths, it probably also led to some overcounting (i.e., reduced specificity), particularly among older women. For example, the MMRC for Texas reported that 50% of maternal deaths in 2012 were false positives (i.e., the women were not pregnant or postpartum at the time of death); most of these errors resulted from reporting problems with the pregnancy checkbox (Baeva et al. 2018; MacDorman, Declercq and Thoma 2018; Callaghan 2020). To mitigate the possibility of false positives, NCHS modified the coding for maternal deaths in 2018. Checkbox-only cases (i.e., deaths in which the only indication of pregnancy within the past year was from the checkbox item) were no longer coded as maternal deaths for female decedents aged 45–54; previously, that coding rule was used only for women aged 55 and older (Hoyert and Miniño 2020). The 2018 coding method reduced the overall MMR in 2018 by 15%, but the reduction was especially large at ages 40 and older (53%).

The introduction of the 10th Revision of the International Classification of Diseases (ICD-10) and the increasing use of record linkage may have also increased identification of maternal deaths (Joseph et al. 2017). Hoyert (2007) reported that the implementation of ICD-10 resulted in a 13% increase between 1998 and 1999 in the number of maternal deaths identified because of the addition of more specific maternal-related codes in the ICD (i.e., codes O26.8, to identify primarily renal disease, and O99, for other maternal diseases classifiable elsewhere).

In conclusion, the ability to evaluate trends in maternal mortality over time in the U.S. is complicated by inconsistencies in definitions (e.g., maternal death, pregnancy-related death, pregnancy-associated death), variations over time and across states in the inclusion of a pregnancy checkbox, and differences in adjustment methods.

WHAT REMAINS TO BE INVESTIGATED?

There appears to be disagreement about how maternal mortality should be defined and measured. Under the current CDC definition, women who die as a result of homicide, suicide or drug overdose during or within one year of pregnancy are categorized as a pregnancy-associated death rather than a pregnancy-related death (Noursi et al. 2020). Oud (2015) suggests that the characterization of pregnancy-associated deaths should be broadened to include contributors and conditions unrelated to pregnancy, which could help identify points of intervention earlier in the sequence of events that ultimately results in death. Others argue that maternal mortality rates are incomplete when the denominator is based only on live births (Studnicki et al. 2017). Riffe (2011) estimates the maternal mortality incidence rate (i.e., the denominator is maternal exposure) rather than the commonly used MMR (which uses live births in the denominator). He concludes that the MMR may overestimate maternal mortality at the highest ages of childbearing but underestimate it at peak childbearing ages.

Also, validity of maternal mortality could be improved by additional data quality checks within the NVSS to validate maternal deaths, improved assessment of “incidental causes” of maternal deaths, and ability to link maternal and infant health records (Chinn et al. 2020). NCHS acknowledges that the vital statistics systems need to be updated to be more flexible and to provide data quality checks in real time as deaths and causes of death are recorded: for example, a pop-up prompt that requests validation of information that appears in error (National Center for Health Statistics 2021).

Levels of Trends in Maternal Mortality in the U.S.

Maternal mortality ratios declined rapidly between 1928 (when penicillin was introduced) and 1950, and they continued to decline more slowly up until the early 1980s (Creanga 2018). Medical progress (in particular the use of antibiotics, safer and more systematic blood transfusion, and better management of preexisting conditions such as hypertension) as well as improvement in the standards of living (as regards nutrition and access to quality care) have driven this favorable trend (Singh 2021). After 1998, maternal mortality appears to have increased in the U.S. and especially after the early 2000s (Neggers 2016). Unfortunately, it is difficult to determine whether the recent trends reflect a true increase in maternal mortality or whether they are simply a statistical artifact resulting from improvements in ascertainment methods and changes in classification (Creanga 2018).

In particular, variation over time and across states in the inclusion of a pregnancy checkbox has made it difficult to assess the real trends in maternal mortality over time in the U.S. MacDorman et al. (2016) estimated the trend in maternal mortality between 2000 and 2014 after correcting for the adoption of pregnancy checkboxes. They concluded that most of the increase resulted from the introduction of checkboxes (also see National Center for Health Statistics 2021). The raw, unadjusted MMR more than doubled between 2000 (9.8 per 100,000 live births) and 2014 (21.5), whereas the adjusted MMR increased by only 27% (from 18.8 in 2000 to 23.8 in 2014 among 48 U.S. states plus the District of Columbia). Based on data from 2008-09 to 2013–14 for 27 states plus the District with comparable reporting of maternal mortality, MacDorman, Declercq and Thoma (2017) found that the increase in maternal mortality was concentrated among women aged 40 and older and maternal deaths resulting from nonspecific causes, which may suggest that overreporting of maternal deaths increased over time.

Similarly, Joseph et al. (2017) found that most of the increase in the MMR between 1999 and 2014 resulted from increases in deaths associated with two new ICD-10 codes: O26.8 (other specified pregnancy-related conditions) and O99 (other maternal diseases classified elsewhere). The result of these additional codes was to include as maternal deaths those due to indirect maternal causes, which were previously unidentified (Singh 2021). When deaths from those causes were excluded, there was no increase in maternal mortality. After adjusting for improvements in surveillance (i.e., the staggered implementation of separate pregnancy question and pregnancy checkboxes on death certificates and the introduction of ICD-10 codes), no significant increase was seen in maternal mortality between 1993 and 2013 (Joseph et al. 2017).

When NCHS resumed published maternal mortality statistics in 2020, they also published several analyses evaluating the effects of the changes over time in data collection. Using more comparable data across states, NCHS concluded that most of the observed increase in the MMR resulted from changes in methods of data collection rather than a true increase in maternal mortality. For example, using the pre-2003 coding method (i.e., without the use of a pregnancy checkbox), the MMR would have been slightly *lower* (8.7 per 100,000 live births) in 2016 than it was in 2002 (8.9) (Hoyert, Uddin, and Miniño 2020). A second analysis used regression discontinuity modeling to evaluate the impact of staggered implementation of the checkbox (Rossen et al. 2020). They found that revision of the death certificate resulted in a large increase in the maternal mortality rate (nearly doubling the MMR), but most of the observed increase was a statistical artifact. They predicted the trend in MMR under two scenarios: 1) assuming no pregnancy checkbox at any point and 2) assuming all states had the checkbox throughout 1999–2017. In both scenarios, no significant change was seen in the predicted MMR between 1999 and 2017, although maternal mortality did increase among women aged 40 and older and among non-Hispanic whites, whereas it declined among non-Hispanic/Latina Black/African Americans, Hispanic/Latinas and among some younger age groups (e.g., 30–34) (Rossen et al. 2020). Nonetheless, the predicted MMR if there were

no pregnancy checkbox throughout the period from 1999 to 2017 suggested a steady increase in maternal mortality after 2007 (Rossen et al. 2020, Table III).

A downward trend in maternal mortality was recorded between 2017 and 2018, but it has also been attributed to changes in the way deaths are classified: in response to studies suggesting that, in some areas, reporting physicians erroneously checked the pregnancy box for older women, the CDC changed its coding methods (Singh 2021). Between 2018 and 2020, maternal mortality in the U.S. rose again from 17.4 in 2018 to 20.1 in 2019 (a 15% increase) and again in 2020 (to 23.8, an 18% increase relative to 2019) (Hoyert 2022). Those increases postdate the modification of the methods for coding maternal mortality in the U.S. and, thus, cannot be explained by changes in ascertainment. The rise in 2020 may be at least partly a result of the COVID-19 pandemic. The increase in the MMR between 2019 and 2020 was especially dramatic among women aged 40 and older, where it increased by 43% (from 75.5 in 2019 to 107.9 in 2020), although there was also a small but significant 15% increase in the MMR among women aged 25–39 (from 19.9 to 22.8); among women younger than 25, the rise was smaller (12.6 to 13.8, an increase of 10%) and not significant (Hoyert 2022)

WHAT REMAINS TO BE INVESTIGATED?

In the past, there were reasons to think maternal mortality was underestimated in the U.S. With the addition of the pregnancy checkbox, some overestimation of maternal deaths particularly at older maternal ages may have occurred. The 2018 coding methods attempted to address that problem. One might ask, Are further refinements needed to improve the sensitivity and specificity? How accurate are the post-2018 methods for identifying maternal deaths via NVSS? Why has maternal mortality continued to rise between 2018 and 2020 when there was no change in methodology? To what extent did COVID-19 contribute to the rise in maternal mortality in 2020, particularly among women aged 40 and older? Issues of data quality, the reporting of maternal status on the death certificate, and cause-of-death ascertainment require extensive analysis and comparison of sources that are not publicly accessible. However, statistical information from the National Vital Statistics System provided by the National Center for Health Statistics could help answer questions regarding the causes of the increase in maternal mortality since 2018.

International Comparisons

Estimates from the World Health Organization (2019, Annex 17) for the MMR in 2017 suggest that maternal mortality is much higher in the U.S. (19 per 100,000 live births) than in many other high-income countries such as Canada (10), France (8), the UK (7), Germany (7), Australia (6), Japan (5), Spain (4), and Italy (2). Yet, in 2000, the MMR for the U.S. (12) was actually lower than for Europe as whole (20; see Annex 16), although it was still slightly higher than the MMRs for northern (10), western (9), and southern Europe (7). The gap between the U.S. and other high-income countries widened between 2000 and 2017 because the MMR increased by 58% in the U.S., whereas it declined in most other high-income countries over the same period. For example, between 2000 and 2017, the MMR declined by 50% in Italy, 44% in Japan, 30% in the UK, 20% in France and 14% in Australia. Based on data for 2018, the Organisation for Economic Co-operation and Development (OECD), an intergovernmental partnership of highly industrialized countries, ranked the U.S. at the bottom of the group, just before Mexico (OECD 2020).

Other estimates based on the Global Burden of Disease (Kassebaum et al. 2014, Table 1) also suggest that the MMR in 2013 was far higher in the U.S. (18.5) than in Canada (8.2), high-income countries in Asia-Pacific (7.9), Australia (4.8), Central Europe (8.8), Western Europe (6.3) and developed countries as a whole (12.1). However, the U.S. disadvantage was much smaller in 1990, and in some cases, the U.S. had an advantage. Whereas the U.S. experienced an increase in the MMR during 1990–2013 (+1.7% per year),

most other high-income regions enjoyed a decline (−1.4% per year for developed countries as a whole, but the annual rate of decline was even greater in central Europe −7.4%, western Europe −3.1%, and for high-income countries in Asia-Pacific −3.2%).

A comparison of the MMR in 2018 for the U.S. relative to 10 other high-income countries (Australia, Canada, France, Germany, the Netherlands, Norway, Sweden, Switzerland and the U.K.) also concluded that maternal mortality was more than twice as high in the U.S. (17.4) compared with the other 10 comparison countries, where the MMR ranged from 1.7 for New Zealand to 8.7 for France (Tikkanen et al. 2020).

Unfortunately, international comparisons are complicated by intercountry differences in the methods for identifying maternal deaths. Comparisons of trends across countries are further challenged by changes over time in methodology. As noted in the previous section, multiple studies suggest that most, if not all, of the recent rise in maternal mortality in the U.S. is simply a statistical artifact. Thus, one must be very cautious when comparing levels and trends in maternal mortality across countries. However, even accounting for differences in reporting and classification practices, the U.S. appears as an outlier for its level of maternal mortality compared with other high-income countries (Collier and Molina 2019).

WHAT REMAINS TO BE INVESTIGATED?

The extent to which measurement of maternal mortality is comparable across countries remains unclear. Furthermore, the trends over time may not be comparable across countries. For the U.S., the rise in the MMR reported by WHO (2019) and Kassebaum et al. (2014) is less dramatic than the trend implied by the observed values reported by NCHS. For example, WHO (2019) estimated that the MMR in the U.S. rose from 12 in 2000 to 19 in 2017, whereas the corresponding values reported by NCHS were 9.8 in 2000 (Rossen et al. 2020, Table III) and 21.6 in 2017 (Hoyert 2022). As noted above, the observed values reported by NCHS are misleading because most (if not all) of the apparent increase in maternal mortality is a statistical artifact (Joseph et al. 2017; Hoyert, Uddin, and Miniño 2020; Rossen et al. 2020). An international comparison of the format of death certificates and an analysis of differences in the procedures to classify maternal deaths across countries would contribute to better understanding of the role of differential reporting in these country-wide variations.

Causes of Death

The distribution of pregnancy-related mortality in the U.S. by cause has shifted over time. Between 1987–90 and 2011–13, a substantial decline took place in the proportion of pregnancy-related deaths resulting from hemorrhage (from 29% to 11%) and hypertensive disorders (from 18% to 7%), whereas increases were seen in the share owing to cardiovascular conditions (from 3% to 16%), cardiomyopathy (from 6% to 11%), cerebrovascular accident (from 4% to 7%), and other medical conditions (from 9% to 15%) (Creanga et al. 2017; Creanga 2018, Figure 3). In 2014–17, cardiovascular (i.e., 12% cardiomyopathy, 8% cerebrovascular and 16% other cardiovascular) and other medical conditions (13%) accounted for nearly half of all pregnancy-related deaths (Centers for Disease Control and Prevention 2020). In contrast, fewer than one-third of pregnancy-related deaths currently result from infection/sepsis (13%), hemorrhage (11%) and hypertensive disorders of pregnancy (7%) (Centers for Disease Control and Prevention 2020; also see Baptiste and d'Alton 2019). The rising share of maternal deaths attributable to cardiovascular conditions remains unexplained, but it has been speculated that increasing maternal age, the rise in the prevalence of peripartum cardiomyopathy and other risk factors (obesity, diabetes and hypertension in particular) among pregnant women, the multiplication of twin pregnancies, and better reporting might have all contributed (Collier and Molina 2019). Cardiovascular-related conditions are particularly prevalent as a cause of

maternal death among Black/African American women (MacDorman et al. 2021b). Causes of early maternal deaths have also been linked to later maternal deaths. In particular, studies have showed that women with gestational diabetes and preeclampsia are also more likely to develop metabolic and cardiovascular diseases within a year of giving birth (Lappen, 2015; Louis et al. 2015).

The timing of maternal deaths relative to the end of pregnancy also varies by cause. Nearly half (45%) of deaths from cardiomyopathy occur more than 42 days postpartum and, thus, would be classified as a "late maternal death" rather than a "maternal death." In contrast, the vast majority of deaths from hemorrhage (>99%), hypertensive disorders of pregnancy (>95%) and infection (94%) occurred within 42 days postpartum (Petersen et al. 2019a).

Beyond these medical causes biologically associated with the health conditions of women during pregnancy and the circumstances of delivery, nonmedical causes have been shown to contribute sometimes significantly (e.g., 49% in a study conducted in Philadelphia over a 4-year period). Such causes include violence (motor vehicle accidents, homicide and suicide) as well as substance abuse, including unintentional drug overdoses (Collier and Mollina 2019; Mitra, Schuster and Ananth 2020).

WHAT REMAINS TO BE INVESTIGATED?

The above statistics are based on pregnancy-related mortality rather than maternal mortality per se. Maternal deaths in 2019 were reported by cause, but the list of causes was not very detailed (Xu et al. 2021, Table 16). Most of the 754 maternal deaths were attributed to "all other direct obstetric causes" (320) and "indirect obstetric causes" (224) with no further disaggregation. Additional work using multiple cause-of-death data could contribute to a better understanding of the morbidity process leading to maternal death in the U.S.

Disparities (Geographic, Racial/Ethnic, Socioeconomic)

RACE/ETHNICITY

Large racial disparities are found in maternal mortality, and those differentials have persisted since at least 1969 (Fang, Madhavan and Alderman 2000; Singh 2021). In 2019, the MMR among non-Hispanic/Latina Black/African American women (44.0 per 100,000 live births) was 2.5 times the rate for non-Hispanic/Latina white women (17.9) and 3.5 times the rate for Hispanic/Latinas (12.6) (Hoyert 2021). The Black/African American-white disparity in maternal mortality appears to have widened during the COVID-19 pandemic: in 2020, the MMR for non-Hispanic/Latina Black women was 2.9 times that of non-Hispanic/Latina white women and more than 3 times that of Latinas (Hoyert 2022). Even after controlling for age, education and income, the risk of a maternal death for non-Hispanic/Latina Black/African American women is 2.5 times that of non-Hispanic/Latina white women (Harper et al. 2004; Maykin and Tsai 2020; Surgo Ventures 2021). Black/African American women are more likely to die from all top causes of maternal mortality compared with white women (i.e., embolism, hemorrhage, preeclampsia, infection and cardiomyopathy), and their deaths are more often preventable than those of white women (44% versus 30%) (Louis et al. 2015). Between 2019 and 2020, the MMR increased significantly among non-Hispanic/Latina Black/African American women (from 44.0 to 55.3) and Latinas (from 12.6 to 18.2), but the increase was smaller and not significant for non-Hispanic/Latina white women (17.9 to 19.1) (Hoyert 2022).

Similarly, earlier studies based on pregnancy-related mortality ratios (PRMRs) in 2007–16 found that compared with non-Hispanic/Latina white women, the PRMR was more than three times as high for non-Hispanic/Latina Black/African American women and more than twice as high for Native American/

Indigenous Resident/Native North American women, but only slightly higher for Asian/Asian American/Pacific Islanders and slightly lower for Latinas (Petersen et al. 2019b). The risk of dying during childbirth for Native American/Indigenous Resident/Native North American women has been showed to be the second highest after that for non-Hispanic/Latina Black/African American women (Louis et al. 2015), and it was found to be particularly high for those living in Native American/Indigenous Resident/Native North American reservations or areas with a high concentration of that group (Surgo Ventures 2021).

SOCIOECONOMIC STATUS

The evidence suggests that the PRMR for high school graduates is more than 2.5 times that of college graduates (Petersen et al. 2019a; Petersen et al. 2019b). A systematic review of the social determinants of pregnancy-related mortality and morbidity concluded that most studies found educational attainment associated with higher risk of maternal mortality (Wang et al. 2020). However, the association between education and maternal mortality appears to be weaker for non-Hispanic/Latina Black/African American and for Hispanic/Latina women than for non-Hispanic/Latina white women (Singh 2021). One of the most striking findings of these studies is that the racial gap in mortality increases with the level of education and is most pronounced among those with a college degree, with maternal mortality rates 4 times higher for non-Hispanic/Latina Black/African American compared with non-Hispanic/Latina white women (Singh 2021).

A few studies have found variation in maternal mortality using other SES measures, particularly at the individual level (because maternal mortality is so rare and death certificates do not include information about income, wealth or occupation). However, Wang et al. (2020) found a couple of studies that evaluated the association with income at the zip code level: one found low-income zip codes had higher pregnancy-related mortality than higher-income zip codes (Harper et al. 2004), and the other found a similar association, although the association was not significant among non-Hispanic/Latina Black/African Americans (Fang, Madhavan and Alderman 2000). This research has been supported by Singh (2021), who found a clear socioeconomic gradient of maternal mortality when classifying women into socioeconomically homogeneous groups of counties. He also found that similar trends (a decline up to the early 1980s, followed by a plateau and then an increase since the end of the 1990s) were experienced by all socioeconomic categories of women.

GEOGRAPHIC

Evidence suggests that the MMR in 2017 was higher in the South (R^2=1.26, 95% CI 1.14–1.40) and lower in the Northeast (R^2=0.73, CI 0.61–0.87) compared with the U.S. as a whole (Snyder et al. 2020). Another study compared the MMR during 1999–2007 for eight states in the Mississippi Delta region versus the other 42 non-Delta states in the U.S. and found that the odds of maternal death was 1.4 times (95% CI 1.2–1.6) higher in Delta counties compared with non-Delta counties or non-Delta states (Smith et al. 2014). An earlier study that examined the MMR in 2003–07 by U.S. state showed significant variation within each region (Singh 2010): states where the MMR was at least 50% higher than the national average included Idaho, Oklahoma, Mississippi, Michigan, New York, New Jersey, Maryland and the District of Columbia, whereas the MMR was at least 50% lower than the national average in Alaska, North Dakota, Minnesota, Indiana, Massachusetts, Rhode Island and Maine.

Studies comparing women in rural versus urban areas have found large differences in maternal mortality between these two groups, with a 50% higher risk of death for women living in nonmetropolitan areas over the 2013–17 period compared with those in metropolitan areas. The risk of dying increases progressively with the degree of rurality so that women in small rural towns have nearly twice the risk of dying in childbirth than those in inner cities (Singh 2021).

WHAT REMAINS TO BE INVESTIGATED?

Because maternal mortality is rare, information about racial/ethnic disparities is generally limited to larger ethnic groups. For Native Americans/Indigenous Residents/Native North Americans and Asian/Asian American/Pacific Islanders, estimates are based on pregnancy-related mortality rather than maternal mortality per se. Both of those groups are very heterogeneous, but we have no information about more specific subgroups.

The only indicator of SES on death certificates is educational attainment. Information about disparities by income, wealth or occupation is limited to aggregate-level analyses that compare counties (or some other geographic unit).

It remains unclear whether geographic variation in maternal mortality results predominantly from differences in population composition (e.g., distributions by race/ethnicity and socioeconomic status) or whether it may reflect state-level differences in policy and access to quality care. A combination of demographic and other types of data could usefully address this issue.

Factors Driving Trends and Differentials

EXPLANATIONS FOR THE APPARENT RISE IN MATERNAL MORTALITY

One of the most important factors driving the increasing trend in maternal mortality appears to be the introduction of the pregnancy checkbox, which increased the identification of maternal deaths, some of which may have been misclassified as maternal deaths, particularly among women aged 40 and above (Davis et al. 2017); see also the "Measurement and Data Quality Issues" section. Other factors that have been proposed as potential contributors to increased maternal mortality are shifts in the maternal age distribution, more cesarean deliveries, increased prevalence of preexisting health conditions (e.g., obesity, diabetes) and restrictions on access to abortion (Collier and Molina 2019).

Davis et al. (2017) investigated the contribution of increasing maternal age because previous studies had indicated increasing risks of maternal mortality by age. The excess risk for older women appears to have continued recently as Singh (2021) showed that women aged 35–39 years at the time of delivery had a 2.2 times higher risk of dying in childbirth than women below the age of 20, and women aged 40 years and above had a 17.7 times higher risk of dying. For Black/African American women, variations by age appears to be even larger, with a 4.1:1 and a 29.3:1 ratio of risks between the corresponding groups of women. However, Davis et al. (2017) concluded from their study that shifts in the maternal age distribution played little role in explaining the apparent increase in maternal mortality. Although there was a shift toward older maternal ages between the late 1970s and early 2000s, they found no substantial increase in the MMR over that period. In contrast, the MMR more than doubled between 1998–2002 and 2008–12 among states that adopted the pregnancy checkbox, and 95% of that increase resulted from increases in age-specific MMRs rather than increases in maternal age (Davis et al. 2017).

Others have suggested that caesarean-section rates, which rose more than 50% between 1996 (20.7%) and 2017 (32.0%), may have contributed to increased maternal mortality (Collier and Molina 2019; Singh 2021). Clark and colleagues found that cesareans deliveries were associated with a 10 times higher risk of maternal mortality compared with vaginal deliveries (Clark et al. 2008). Caesarean deliveries tend to exacerbate the effects of pregnancy-related conditions like venous thromboembolism, hemorrhage and infection (Louis et al. 2015). However, an analysis of population-level factors that contributed to trends in maternal mortality during 1997–2012 found little evidence that increases in cesarean delivery or shifts to

higher maternal age played a notable role (Nelson, Moniz and Davis 2018). In contrast, they concluded that the adoption of the standard pregnancy checkbox and rising prevalence of obesity each contributed 31% of the increase in maternal mortality; an increase in births to women with diabetes also accounted for another 17% of the rise in maternal mortality (Nelson, Moniz and Davis 2018).

Another study revealed an association between restrictions on access to abortion and increased maternal mortality, particularly for women of color (Addante et al. 2021). This state-level analysis showed little difference in the MMR in 1995 between states with policies classified as restrictive, neutral or protective of abortion access, but by 2017 the MMR was almost 70% higher in restrictive states than in protective states. In models that adjusted for policy, state and year, they found that the MMR increased more in restrictive states than in neutral states, whereas a nonsignificant decrease in the MMR was seen in protective states.

In conclusion, the recent increase in maternal mortality appears to be largely a result of the implementation of the pregnancy checkbox (Davis et al. 2017; Nelson, Moniz and Davis 2018) but may have also been exacerbated by increases in the prevalence of preexisting conditions (e.g., obesity, diabetes) (Nelson, Moniz and Davis 2018) and policies that restricted access to abortion (Addante et al. 2021).

FACTORS DRIVING DISPARITIES IN MATERNAL MORTALITY

Individual-level factors that are thought to explain why some women are more vulnerable to maternal mortality than others include SES and prevalence of preexisting chronic conditions (Howell 2018; Petersen et al. 2019b; Noursi, Saluja and Richey 2021). SES is a distal factor, whereas preexisting health conditions such as hypertension, cardiovascular disease and diabetes are more proximate risk factors. Thus, the prevalence of preexisting health conditions may be, at least partly, a consequence of SES. The other factors put forward to explain disparities in maternal mortality are also associated with SES (the higher rates of unintentional pregnancies, delayed prenatal care and lack of health insurance among Black/African American compared with white women) (Louis et al. 2015). The fact that at similar levels of poverty, the risk of a pregnancy-related death is lower for Hispanic/Latina than for non-Hispanic/Latina Black/African American women is attributable to the higher prevalence of protective characteristics among the former compared with the later: Hispanic/Latina women appear to benefit from a strong family structure, a healthy migrant effect and lower rates of harmful behaviors, such as smoking (Louis et al. 2015).

At the community level, access to prenatal care and the availability and quality of obstetric care are likely to contribute to disparities in maternal mortality (Howell 2018; Petersen et al. 2019b; Noursi, Saluja and Richey 2021). For example, Black/African American women are more likely than white women to give birth in hospitals that have lower quality of care (Creanga et al. 2014). Various studies reported by Collier and Molina (2019) estimate that a third to half of the racial disparities in maternal mortality might be attributed to differences in the quality of in-hospital maternal care.

However, macrolevel factors such as structural racism could also play a fundamental role in generating inequality at the individual and community levels (Bailey et al. 2017). Structural racism may take the form of implicit bias that affects patient-provider interactions, treatment decisions and health outcomes (Hall et al. 2015; Collier and Molina 2019). Mistrust of the medical establishment associated with perceived discrimination by health care professionals, some of which has been documented (Hall et al. 2015), is further associated with lower prenatal care utilization, delays in seeking care and adherence to treatment plans, which could disproportionately affect poorly served minority populations (Collier and Molina 2019). Structural racism is also reflected by residential segregation, which has important implications for availability and quality of health care (Bailey et al. 2017). Some research suggests that income inequality may also contribute to racial inequality in pregnancy-related mortality (Vilda et al. 2019), but it is based on aggregate-level analyses. Although it does control for state-level measures of racial (i.e., percent non-

Hispanic/Latina Black/African American) and socioeconomic composition (i.e., median household income, percent of those aged 25 and older who are college graduates, percent of civilian population aged 16 and older who are unemployed), the analysis cannot distinguish between the effect of individual-level income versus macrolevel income inequality.

WHAT REMAINS TO BE INVESTIGATED?

Many point to structural racism as a root cause of disparities in maternal mortality, but it is difficult to quantify the contribution of structural racism. Area-level analysis of the relationship between measures of structural racism and maternal mortality might provide a viable avenue of research to investigate the link between the two phenomena using publicly available data. Data from the National Vital Statistics System could, for instance, be linked at the area level to indicators of systemic racism and discrimination such as those suggested by Dougherty and colleagues (2020) or Bailey, Feldman and Bassett (2021).

Interventions and Policies to Reduce Maternal Mortality in the U.S.

A report from the CDC based on data on maternal deaths during 2008–17 provided by 14 MMRCs concluded that two-thirds of maternal deaths were preventable (Davis, Smoots and Goodman 2019). Deaths from hemorrhage and cardiovascular or coronary conditions were deemed to be the most preventable Zaharatos et al. 2018).

HISTORY

Since 2006, many initiatives at the state and national levels have been aimed at reducing maternal mortality. We begin by reviewing an initiative in California because it spurred efforts at the national level (Lu 2018).

CALIFORNIA

The California Department of Health initiated a public-private collaboration in 2006 aimed at improving the quality of maternity care (Main, Markow and Gould 2018). Based on the first two years of case reviews, they identified obstetric hemorrhage and preeclampsia as the most preventable causes of maternal mortality. An obstetric hemorrhage task force was established in 2008; they developed and released the obstetric hemorrhage toolkit in 2009. A Preeclampsia Task Force was formed in 2010 and developed a toolkit for preeclampsia. By 2016, 92% of California hospitals had adopted the obstetric hemorrhage toolkit, and 75% had adopted the preeclampsia toolkit (Main, Markow and Gould 2018).

A critical component of quality improvement is the ability to measure progress in a timely manner. California pioneered rapid-cycle linkage of birth certificates and hospital discharge diagnosis files via a secure web portal, which also included supplemental data from electronic health records and chart reviews (Main 2018). Data collection and processing were designed to minimize burden and cost (Main, Markow and Gould 2018).

During 1999–2006, the MMR was generally rising in California as in the U.S. as a whole, but California began to diverge from the national trend after 2006. The U.S. national MMR increased 65% between 2006 (13.3) and 2013 (22.0), whereas the MMR in California declined 57% over that same period, from 16.9 in 2006 to 7.3 in 2013 (Lu 2018; Main 2018). The correlation between the downward trend in maternal mortality in California and the efforts to improve the quality of maternity care is suggestive but does not prove causation (Main, Markow and Gould 2018).

Because maternal mortality is rare, assessments often focus on maternal morbidity as an outcome rather than mortality. A controlled trial focused on reducing serious complications from obstetric hemorrhage found that severe maternal morbidity among hemorrhage patients declined by 20.8% among the 99 participating hospitals, whereas a nonsignificant 1.2% reduction was seen among the 48 hospitals in the control group (Main 2018).

THE U.S.

At the national level, the effort to reduce maternal mortality and severe maternal mortality began in 2012 with the formation of the National Partnership for Maternal Safety, which identified the need to develop best practice bundles (or safety toolkits) to address the three most preventable causes of maternal death: obstetric hemorrhage, severe hypertension and venous thromboembolism (Mahoney 2018). The first practice bundle—for obstetric hemorrhage—was published in 2014. Later that same year, the Alliance for Innovation on Maternal Health (AIM) was established with funding from the Health Research Services Administration. In 2015 the Building US Capacity to Review and Prevent Maternal Deaths initiative was developed to remove barriers to fully functional MMRCs (Zaharatos et al. 2018). In 2018, the Preventing Maternal Deaths Act (H.R. 1318) authorized federal funding to support the work of state MMRCs (Ahn et al. 2020).

SPECIFIC INTERVENTIONS

Most of the interventions have focused on using evidence-based toolkits designed to standardize the provision of maternal care and improve quality. Other efforts have employed other means to improve care or expand access to care. It is difficult to determine how these interventions may affect maternal mortality because formal evaluations of their effectiveness are limited, particularly with respect to the rare outcome of maternal death.

EVIDENCE-BASED TOOLKITS (MATERNAL SAFETY BUNDLES

One of the key components of the initiatives described above was the efforts to standardize maternity care using evidence-based toolkits (Metz 2018). Such toolkits have been developed for obstetric hemorrhage, preeclampsia/severe hypertension, venous thromboembolism, safe reduction of primary cesarean birth, obstetric care for women with opioid use disorder, postpartum care basics, reduction of peripartum racial/ethnic disparities and support after a severe maternal event (Main, Markow and Gould 2018; Ahn et al. 2020). As noted above, a formal evaluation indicated the effectiveness of efforts to reduce serious complications from obstetric hemorrhage, but the outcome was severe maternal morbidity rather than maternal mortality (Main 2018).

OTHER EFFORTS FOCUSED ON IMPROVING MATERNITY CARE

A telehealth intervention in Georgia (CenteringPregnancy) sought to improve patient education via videoconferencing with a maternal-fetal specialist; preterm deliveries decreased from 18.8% at baseline to 8% at the end of the 18-month intervention (Ahn et al. 2020; Association of State and Territorial Health Officials 2018). Various projects have sought to educate clinicians about racial and ethnic disparities in maternal outcomes and the problem of implicit bias (Howell 2018; Ahn et al. 2020). A recent trend is also seen toward patient-centered care in obstetrics, but the focus is primarily on reducing primary cesarean deliveries and preterm births rather than on maternal mortality per se (Howell 2018; Ahn et al. 2020). Calls have also been made to increase the implication of midwives in maternal care, during pregnancy, at the time of delivery and immediately after giving birth (Renfrew et al. 2014; Sandall et al. 2016). Studies have

showed that the much larger ratio of midwives to population in high-income countries outside of the U.S. might explain at least part of their success in controlling maternal mortality (Tikkanen et al. 2020).

EXPANDING ACCESS TO CARE

The Affordable Care Act (2010) expanded health care coverage and gave states the option of expanding Medicaid eligibility; since then, 36 states and the District of Columbia have expanded Medicaid (Villavicencio, McHugh and Edmonds 2020; Kumar, Borders and Simon 2021). Even if a state did not expand eligibility for Medicaid, pregnant women are eligible to receive federally mandated pregnancy-related Medicaid throughout the pregnancy and for 60 days postpartum (Villavicencio, McHugh and Edmonds 2020). In 2019 the Health Resources and Services Administration (HRSA) initiated a project to encourage the use of remote pregnancy monitoring to increase virtual access to care for women in rural and medically underserved areas (Association of State and Territorial Health Officials, 2018; Ahn et al. 2020).

The current administration has sought to promote a range of measures and policies to reduce maternal mortality and associated disparities with the Maternal CARE Act and the Back Maternal Care Momnibus Act. These interventions include the extension of Medicaid coverage up to one year after giving birth, training programs around implicit bias for health care providers, and the establishment of Maternal Mortality Review Committees in states where they so not exist (White House 2021). Even if these acts are voted into law by Congress, it will take several years before their effects can be evaluated.

WHAT REMAINS TO BE INVESTIGATED?

It is difficult to judge the effectiveness of many interventions because they are not formally evaluated. Given the rarity of maternal death (861 in 2020 according to the 2022 CDC report), it is especially difficult to assess the effect on maternal mortality. If there is any evaluation, it typically focuses on maternal morbidity rather than mortality.

Many other recommendations have not yet been implemented on a wide-scale basis. For example, a report based on data from nine MMRCs recommended the adoption of levels of maternal care to ensure appropriate level of care (Zaharatos et al. 2018). That is, birth centers would be classified according to whether they are able to provide basic care (Level 1), specialty care (Level 2) or subspecialty care (Level 3) or serve as a regional perinatal health care center (Level 4) (Villavicencio, McHugh and Edmonds 2020). Videoconferencing has also been proposed as a means by which higher-level facilities can provide assistance to staff at lower-level facilities in the case of obstetric emergencies (Ahn et al. 2020). More generally, policies to address discrimination in health and the broader social determinants of health (including poverty) would reduce variations in maternal mortality (Collier and Molina 2019).

An analysis by the Commonwealth Fund that compared the U.S. with 10 other high-income countries concluded that the undersupply of maternity providers, particularly midwives, and the lack of access to comprehensive support during the postpartum period contribute to the exceptionally high maternal mortality in the U.S. (Tikkanen et al. 2020). The U.S. and Canada have, by far, the lowest supply of maternity providers among the 11 countries, and the disparities are particularly large for the number of midwives per 1,000 live births: four in the U.S. and Canada versus 25–66 in the other countries (Tikkanen et al. 2020, Exhibit 3). Systematic reviews indicate that midwifery-led care is comparable or better than physician-led maternity care in terms of both maternal and neonatal outcomes as well as patient satisfaction and use of resources, including lower use of potentially harmful interventions (Renfrew et al. 2014; Sandall et al. 2016). In the U.S., midwifery services are not uniformly covered by private insurance, and even when covered, the low supply of midwives limits access (Tikkanen et al. 2020).

As for support during the postpartum period, the U.S. is the only one of the 11 countries that does not guarantee access to at least one home visit after delivery and paid leave to mothers after childbirth (Tikkanen et al. 2020). The WHO recommends at least four health contacts within the first six weeks after delivery (World Health Organization 2015). The Medicaid extension is limited to 60 days postpartum, which can cause a disruption in care during the year following birth (Villavicencio, McHugh and Edmonds 2020). Thus, some recommend extending Medicaid coverage to a full year after birth (Megibow et al. 2021).

Conclusion

After decades of steady declines, maternal mortality reached a plateau in the early 1980s, and it started rising at the end of the 1990s. Most of the increase was artifactual because a new death certificate, designed to better capture maternal deaths, was progressively implemented across the states. However, the rising trend continued beyond 2017, when all U.S. states and the District of Columbia had adopted the new certificate. The trend is particularly worrisome given that all other high-income countries have experienced a continuous decline in maternal mortality over the same period.

The trends have been similar across all segments of the U.S. population, and the large preexisting differences by race and ethnicity, geography and socioeconomic factors have persisted or increased until now. The increasing proportion of at-risk pregnancies or deliveries, related to higher maternal age, the rising prevalence of underlying health factors (obesity, gestational diabetes and hypertension in particular), the increase in the share of cesarean deliveries, and more difficult access to reproductive and prenatal care for women in the most deprived segments of the population appear to have all played a role in both the rising rate of maternal mortality and the various types of disparities reported.

A better understanding of these patterns is complicated by the fact that maternal deaths are a relatively rare event and that publicly available data lack the details necessary to further investigate the recent trends and the associated variations, by race and ethnicity, geographic areas and socioeconomic status. Further research is warranted, however, to reduce the number of women dying from pregnancy-related causes because half to two-thirds of all maternal deaths are preventable. Any intervention reducing the risk of a maternal death would also benefit infants, because the same factors are at play for maternal and child health.

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Project Oversight Group members:

Jean-Marc Fix, FSA, MAAA

Sam Gutterman, FSA, MAAA, CERA, FCAS, CXA, HonFIA

Anji Li, FSA, MAAA, CERA

Monique McBean, FSA, MAAA, CERA

Mischelle Schweickert, FSA, MAAA

Larry N. Stern, FSA, MAAA

Yukki Yeung, FSA, MAAA

At the Society of Actuaries Research Institute:

Jan Schuh, Sr. Research Administrator

Ronora Stryker, ASA, MAAA, Sr. Practice Research Actuary

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Appendix A: Maternal Mortality Organized Bibliography

We have compiled a list of references about maternal mortality and organized them by topic. Note that some of the publications appear under several different sections of the reference list when they are relevant to more than one topic.

MEASUREMENT AND DATA QUALITY

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Society of Actuaries Research Institute
8770 W Bryn Mawr Ave, Suite 1000
Chicago, IL 60631
www.SOA.org