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PREECLAMPSIA

Historical and Recent Changes in Maternal Mortality Due to Hypertensive Disorders in the United States, 1979 to 2018

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ABSTRACT: We evaluated the contributions of maternal age, year of death (period), and year of birth (cohort) on trends in hypertension-related maternal deaths in the United States. We undertook a sequential time series analysis of 155 710 441 live births and 3287 hypertension-related maternal deaths in the United States, 1979 to 2018. Trends in pregnancy-related mortality rate (maternal mortality rate [MMR]) due to chronic hypertension, gestational hypertension, and preeclampsia/eclampsia, were examined. MMR was defined as death during pregnancy or within 42 days postpartum due to hypertension. Trends in overall and race-specific hypertension-related MMR based on age, period, and birth cohort were evaluated based on weighted Poisson models. Trends were also adjusted for secular changes in obesity rates and corrected for potential death misclassification. During the 40-year period, the overall hypertension-related MMR was 2.1 per 100 000 live births, with MMR being almost 4-fold higher among Black compared with White women (5.4 [n=1396] versus 1.4 [n=1747] per 100 000 live births). Advancing age was associated with a sharp increase in MMR at ≥15 years among Black women and at ≥25 years among White women. Birth cohort was also associated with increasing MMR. Preeclampsia/eclampsia-related MMR declined annually by 2.6% (95% CI, 2.2–2.9), but chronic hypertension–related MMR increased annually by 9.2% (95% CI, 7.9–10.6). The decline in MMR was attenuated when adjusted for increasing obesity rates. The temporal burden of hypertension-related MMR in the United States has increased substantially for chronic hypertension–associated MMR and decreased for preeclampsia/eclampsia-associated MMR. Nevertheless, deaths from hypertension continue to contribute substantially to maternal deaths.

Key Words: continental population groups ■ eclampsia ■ live birth ■ maternal mortality ■ preeclampsia

Nonstandard Abbreviations and Acronyms

APC	age-period-cohort
ICD	*International Classification of Diseases*
MMR	maternal mortality rate
NCHS	National Center for Health Statistics

RR	rate ratio

The World Health Organization[1] reported that maternal mortality rates (MMRs) in the United States increased from 12 to 28 per 100 000 live births between 1990 and 2013. However, recent reports from the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention show that this reported increase was an artifact of maternal mortality surveillance.[2–4] The NCHS reports, based on careful recoding and reanalysis of death certificates, showed that MMR in the United States increased following the introduction of a pregnancy checkbox on death certificates in 2003 and its subsequent staggered adoption by the states. Another notable finding was that the effect of the checkbox was cause-of-death dependent; maternal deaths due to nonspecific causes increased substantially, while those due to specific pregnancy-related causes, such as hypertensive disorders, edema, and proteinuria, were unimpacted.[2–4]

Worldwide, hypertensive complications during pregnancy are implicated in over 50 000 maternal deaths annually.[5] In the United States, about 8% to 10% of all pregnancies are complicated by some form of hypertension,[6] with severe preeclampsia[7] and chronic hypertension[8] showing a steady temporal increase over the last 4 decades. Deconstructing the changing profile of maternal deaths due to hypertensive disorders in relation to biological determinants and environmental factors requires an examination of historical trends in an age-period-cohort (APC) framework. MMRs are age dependent, and the steep increase in mortality with advancing age at childbirth has implications for populations where women increasingly delay childbearing.[9] Age effects may be impacted by extraneous factors including specific medical therapies, and mortality rates at a given age can change substantially over time. Such secular variation in age-specific mortality (a period effect) may also be influenced by ascertainment and classification of maternal deaths. Birth cohorts (ie, cohorts defined on the year of birth of women) may be characterized by cumulative exposures to social conditions, lifestyle (eg, obesity), and behavioral factors (eg, smoking or drug use), and such determinants can also impact maternal mortality.

We undertook this study to disentangle the independent contributions of maternal age, year of death (period), and year of birth (birth cohort) on trends in hypertension-related MMR in the United States. We hypothesized that secular increases in obesity could explain, at least partly, any recent temporal increase in hypertension-related MMR.

METHODS

Data Sharing

The data utilized in this study are in the public domain in deidentified form and can be accessed at https://www.cdc.gov/nchs/data_access/vitalstatsonline.htm.

We designed a sequential time series analysis to examine temporal changes in MMR between 1979 and 2018 in the United States. The mortality data assembled by the NCHS includes all deaths in 50 states and Washington, DC, are derived from standard death certificates. We used data on all US live births (ascertained from birth certificates) between 1979 and 2018, which were also assembled by the NCHS and correspond to data on live births in the 50 states plus Washington, DC. Since these data were fully deidentified and publicly available, we did not require ethics approval. The study followed the The Strengthening the Reporting of Observational Studies inn Epidemiology reporting guidelines for cross-sectional studies.

Maternal Deaths

We restricted the study to women aged 15 to 49 years. We first identified deaths related to pregnancy and childbirth, captured in the primary cause-of-death field, and an additional 14 (1979–1998) or 20 (1999–2018) cause-of-death fields on the death certificate. These data were coded based on the *International Classification of Diseases* (*ICD*), *Ninth* (from 1979–1998) *and Tenth* (from 1999–2018) *Revisions*; pregnancy-related deaths were identified as those with codes 630–679 in *ICD, Ninth Revision*, and O chapter codes except O96 and O97 in *ICD, Tenth Revision* (Table S1 in the Data Supplement).[10] We further restricted the analysis to deaths that had hypertensive conditions, specifically chronic hypertension, gestational hypertension, and preeclampsia/eclampsia, listed in the cause-of-death fields. These pregnancy-related maternal deaths and associated rates are hereafter referred to as hypertension-related MMR.

Statistical Analysis

Through an APC modeling approach, we examined changes in hypertension-related MMR in the United States between 1979 and 2018 overall and separately among Black and White women. We began by first examining graphical plots of MMR: (1) MMR examined by age (observations within each period connected) depicting cross-sectional age-specific rates; (2) MMR versus age, observations within each birth cohort connected, depicting longitudinal age-specific rates; (3) MMR by period, observations within each age-class connected; and (4) MMR by cohort, observations within each age-class connected. These analyses helped guide the parametrization of the age, period, and cohorts in the APC framework. APC modeling was based on Poisson regression with MMR modeled as the number of maternal deaths cross-classified by age, period, and cohort (all in single years), with the number of live births as an offset (denominator) in the APC cross-classification.

To overcome the identifiability problem in an APC analysis (any two of the effects is sufficient to determine the third leading to collinearity[11]), we imposed a series of constraints. We first modeled MMR as a function of maternal age, followed by an overall linear trend in MMR (sum of the linear component of period and cohort effects); this estimate is referred to as the drift parameter (ie, annual percent change in MMR). We then assessed deviations from linearity that can be uniquely attributed to the period and cohort effects, referred to as the curvature effect (ie, if the effect of period or cohort on MMR is nonlinear). Models were fit sequentially beginning with age only and then adding the drift parameter and subsequently the period and cohort parameters. APC effects were modeled as smooth functions based on natural splines with 6 knots each.

Impact of Obesity on Maternal Mortality Trends

We examined how secular changes in rates of obesity may have influenced the APC effects on hypertension-related MMR. This was performed because obesity is a strong risk factor for maternal complications, including those related to hypertensive diseases, and the prevalence of obesity has been increasing.[12] We extracted prevalence rates of obesity from the National Health and Nutrition Examination Survey data by period and birth cohorts, where available.[13] We undertook a hierarchical APC analysis[14] based on a weighted Poisson model to evaluate changes in MMR following adjustment for obesity rates. Yearly obesity rates and maternal age were modeled as categorical fixed effects; categorical period variables were included as random effect terms.

Sensitivity Analysis

Given the potential for misclassification of deaths with hypertensive disease as the cause, we undertook a probabilistic bias analysis to correct for differential outcome misclassification. This analysis was based on conservative estimates of sensitivity and specificity for maternal deaths: sensitivity ranging from 0.65 to 0.99 for the 2018 period and 0.80 to 0.99 for the 1980 reference period and specificity ranging from 0.98 to 1.00 for both periods. We replicated the analysis 100 000× for various combinations of sensitivity and specificity parameters based on a uniform distribution and reported the misclassification-adjusted median rate ratio (RR) and 95% CI.

The APC analysis was performed in R implemented in the Epi package[15] in RStudio (version 1.2).[16] Hierarchical APC models were fit in SAS (version 9.4; SAS Institute, Cary, NC). The probabilistic bias analysis was implemented in RStudio based on the episensr() package.[17]

RESULTS

During the 40-year period (1979–2018), there were 155 710 441 live births and 3287 (2.1 per 100 000 live births) hypertension-related maternal deaths. Hypertension-related MMRs were 5.4 (n=1396) and 1.4 (n=1747) per 100 000 live births among Black and White women, respectively. The mean (SD) maternal age was 3 years lower among women (27.0 [6.0] years) who did not die compared with women who died (30.0 [7.4] years). Annual hypertension-related MMRs were stable between 1979 and 2018, but MMRs were 2- to 4-fold higher among Black than White women (Figure S1). The numbers of pregnancy-related deaths with hypertension as the underlying cause and corresponding MMR by maternal age and period are shown in Table 1. Hypertension-related MMR showed a steady increase with advancing maternal age within each period, with the MMR being the highest among women aged 45 to 49 years.

Table 1. Number of Live Births and Hypertension-Related MMRs (per 100 000 Live Births) by Maternal Age, Period, and Maternal Birth Cohorts: United States 1979 to 2018 (Table view)

Period of death	Maternal age, y							Central birth cohort
	15–19	20–24	25–29	30–34	35–39	40–44	45–49	
							1087 (92.0)	1937
						20 862 (9.6)	1167 (85.7)	1942
					127 183 (7.1)	28 391 (7.0)	1640 (61.0)	1947
				502 051 (4.6)	214 660 (3.7)	48 665 (10.3)	2728 (36.6)	1952
			1 017 915 (2.4)	697 298 (1.7)	317 959 (3.5)	67 314 (7.4)	4355 (23.0)	1957
		1 125 164 (1.7)	1 202 858 (0.9)	887 112 (2.4)	384 128 (3.1)	90 124 (4.4)	6132 (16.3)	1962
	506 591 (3.9)	1 142 457 (0.6)	1 278 669 (1.2)	905 511 (1.4)	452 575 (3.8)	104 815 (10.5)	7182 (69.6)	1967
1980	467 761 (1.5)	1 094 950 (2.5)	1 064 615 (1.3)	930 499 (2.5)	484 004 (3.7)	107 266 (9.3)	8228 (121.5)	1972
1985	522 204 (2.5)	966 306 (1.9)	1 089 179 (2.3)	952 787 (1.8)	465 948 (3.0)	112 232 (9.8)		1977
1990	500 112 (0.6)	1 018 922 (1.3)	1 133 747 (2.1)	964 440 (2.5)	529 565 (4.2)			1982

Period of death	Maternal age, y							Central birth cohort
	15–19	20–24	25–29	30–34	35–39	40–44	45–49	
1995	469 423 (1.1)	1 041 847 (1.0)	1 136 047 (1.4)	1 097 846 (1.5)				1987
2000	415 226 (1.2)	953 064 (1.3)	1 155 359 (1.8)					1992
2005	368 165 (1.4)	852 149 (0.9)						1997
2010	230 167 (0.9)							2002
2015								

Table entries denote the total number of live births (MMRs: expressed per 100 000 live births). Period of death refers to the year when women died, and central maternal birth cohort refers to the mid-year (in a 5-y interval) when women were born. Among women who died in 2015 (period) aged 15 to 19 y, the MMR was 0.9 per 100 000 live births. These women would have been born between 1995 and 2000 (central maternal birth cohort 2002). MMR indicates maternal mortality rate.

The separate (unadjusted) associations of age on hypertension-related MMR showed a sharp linear increase in hypertension-related MMR among Black women aged ≥15 years and a sharp increase among White women aged ≥25 years (Figure S2, left). Compared with rates in 1980 (reference period), the age-adjusted RR for hypertension-related MMR declined up to 1990s and plateaued thereafter (Figure S2, middle). Compared with the 1960 reference birth cohort, the RRs for hypertension-related MMR declined in subsequent birth cohorts although CIs were wide (Figure S2, right).

Age-Period-Cohort Models

The results of the APC model for hypertension-related MMR overall and separately among Black and White women are shown in Figure 1. The model showed that advancing age was strongly associated with increasing MMR at age ≥15 years and ≥25 years among Black women and White women, respectively. Age-specific rates were substantially higher in Black compared with White women (Table 2). Compared with 1980, the RRs for hypertension-related MMR decreased up to 1990 and stabilized thereafter; this pattern was similar among Black and White women. Maternal birth cohorts were also associated with MMR: compared with the 1960 reference cohort, MMRs increased marginally overall and among Black and White women in the 1970 birth cohort and declined thereafter. The overall fit of these models was satisfactory (Table S2).

Table 2. Hypertension-Related MMRs (per 100 000 Live Births) for Selected Maternal Ages, Periods, and Maternal Birth Cohorts: United States 1979 to 2018 (Table view)

	All women	White women	Black women
Maternal age, y	MMR (95% CI) per 100 000 live births		
15	1.5 (1.1–1.9)	1.1 (0.8–1.6)	2.1 (1.4–3.1)
20	1.3 (1.1–1.6)	1.0 (0.8–1.2)	2.6 (2.0–3.4)
25	1.3 (1.1–1.5)	0.9 (0.7–1.1)	3.4 (2.6–4.5)
30	1.7 (1.4–2.0)	1.2 (0.9–1.5)	6.3 (4.8–8.4)
35	2.3 (2.0–2.8)	1.7 (1.3–2.1)	8.1 (6.1–10.9)
40	6.3 (5.2–7.6)	4.6 (3.6–5.9)	20.6 (15.4–27.7)
45	22.7 (17.9–28.9)	17.4 (12.6–24.0)	69.3 (47.8–100.4)
49	63.3 (45.8–87.6)	50.2 (32.3–78.1)	182.4 (111.6–298.3)
Year of death	Adjusted rate ratio (95% CI) of MMR		

	All women	White women	Black women
1980	1.00 (reference)	1.00 (reference)	1.00 (reference)
1990	0.70 (0.58–0.84)	0.69 (0.53–0.89)	0.65 (0.48–0.88)
2000	0.78 (0.66–0.92)	0.78 (0.63–0.98)	0.76 (0.58–0.99)
2010	0.80 (0.68–0.95)	0.75 (0.60–0.94)	0.83 (0.64–1.09)
2018	0.86 (0.70–1.05)	0.83 (0.63–1.10)	0.89 (0.65–1.22)
Birth cohort, y	Adjusted rate ratio (95% CI) of MMR		
1930	1.33 (0.84–2.10)	1.27 (0.68–2.35)	1.08 (0.54–2.16)
1940	1.19 (0.89–1.60)	1.17 (0.79–1.73)	1.04 (0.66–1.63)
1950	1.07 (0.94–1.22)	1.07 (0.90–1.27)	0.99 (0.81–1.23)
1960	1.00 (reference)	1.00 (reference)	1.00 (reference)
1970	1.28 (1.13–1.46)	1.22 (1.03–1.45)	1.47 (1.19–1.83)
1980	1.17 (1.05–1.31)	1.13 (0.97–1.32)	1.20 (1.01–1.42)
1990	0.90 (0.80–1.01)	0.89 (0.74–1.05)	0.88 (0.75–1.04)
2000	0.69 (0.52–0.91)	0.69 (0.46–1.04)	0.63 (0.41–0.97)

The MMRs by age are for the reference period 1980 and are not adjusted for other factors. The rate ratios for period and birth cohorts are adjusted for the effects of maternal age. MMR indicates maternal mortality rate; and y, years.

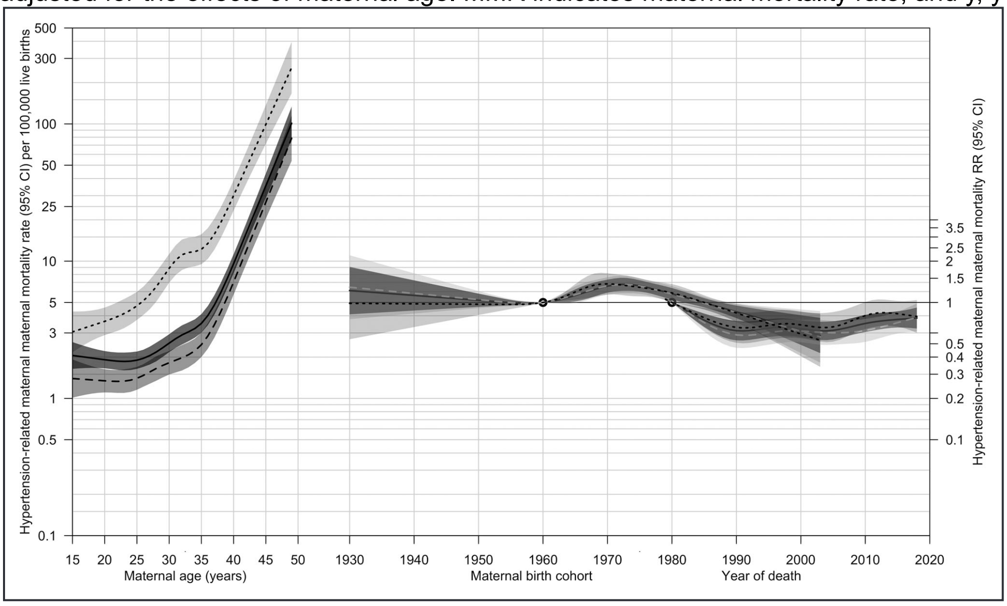

Figure 1. **Age-period-cohort trends in overall and race-specific maternal mortality with hypertensive conditions as the cause in the United States, 1979 to 2018.** Maternal mortality rate (MMR; per 100 000 live births) is shown in relation to maternal age on the *y* axis on the left. The MMR ratio is shown in relation to maternal birth cohort (with the 1960 maternal birth year as the reference) and period (with 1980 as the reference) on the right axis. The shaded bands denote 95% CI. The yearly change in MMR was −0.3% (95% CI, −0.6 to −0.0) for all women (solid line), −0.4% (95% CI, −0.9 to −0.1) for White women (dashed line), and 0.0% (95% CI, −0.5 to 0.5) for Black women (dotted line). Advancing maternal age was strongly associated with increasing MMR after age 25 y, and age-specific rates were substantially higher in Black compared with White women. Compared with 1980, the RRs for hypertension-related MMR showed that the MMR declined up to 1990 and stabilized thereafter. The MMR increased marginally and among White and Black women in the 1970 birth cohort and declined thereafter. RR indicates rate ratio.

The APC analysis for MMR due to preeclampsia/eclampsia showed a strong age effect among women aged ≥25 years (Figure 2). Compared with 1980, MMR associated with preeclampsia/eclampsia showed a steady temporal decline, with an average annual decline in MMR of 2.6% (95% CI, 2.0–3.2) and 2.5% (95% CI, 2.0–2.9) among Black and White women, respectively. No appreciable cohort effects were evident.

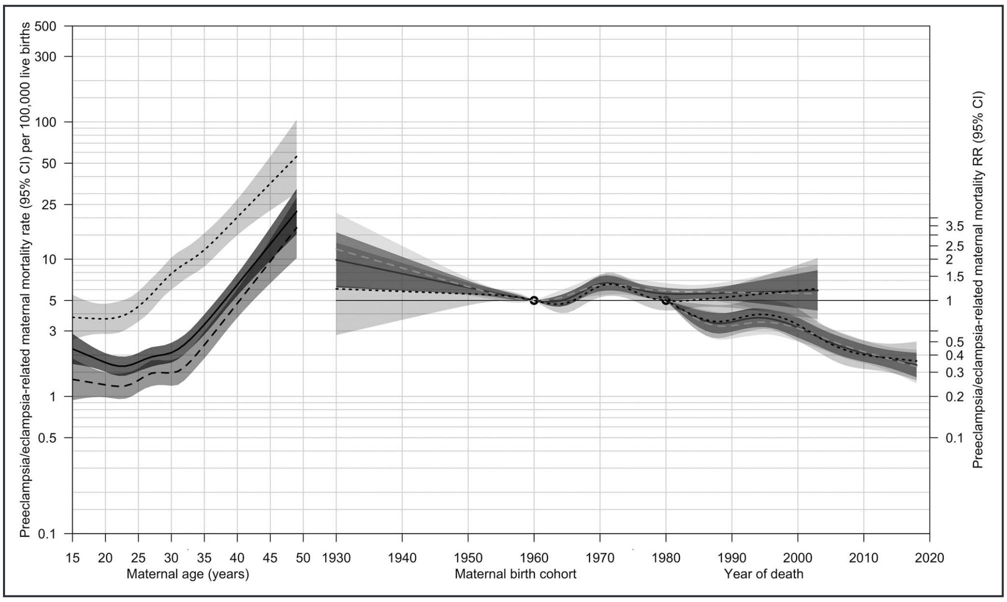

Figure 2. Age-period-cohort trends in overall and race-specific maternal mortality with preeclampsia/eclampsia as the cause in the United States, 1979 to 2018. Maternal mortality rate (MMR; per 100 000 live births) is shown in relation to maternal age on the *y* axis on the left. The MMR ratio is shown in relation to maternal birth cohort (with the 1960 maternal birth year as the reference) and period (with 1980 as the reference) on the right axis. The shaded bands denote the 95% CI. The yearly change in MMR was −2.6% (95% CI, −2.9 to −2.2) for all women (solid line), −2.5% (95% CI, −2.9 to −2.0) for White women (dashed line), and −2.6% (95% CI, −3.2 to −2.0) for Black women (dotted line). The APC analysis shows a strong linear increase in preeclampsia/eclampsia-related MMR among Black women aged ≥30 y and among White women aged ≥35 y. Compared with MMR in 1980, RRs for mortality declined, on average, by 2.5% and 2.6% per year among White and Black women, respectively. No appreciable birth cohort effects were evident. RR indicates rate ratio.

Changes in MMRs associated with chronic hypertension showed a sharp linear increase in MMR with advancing maternal age among both Black and White women (Figure 3). While no cohort effects were seen, the MMR showed a sharp temporal increase: MMR increased annually by 9.1% (95% CI, 7.1–11.1) among Black women and by 9.4% (95% CI, 7.4–11.4) among White women.

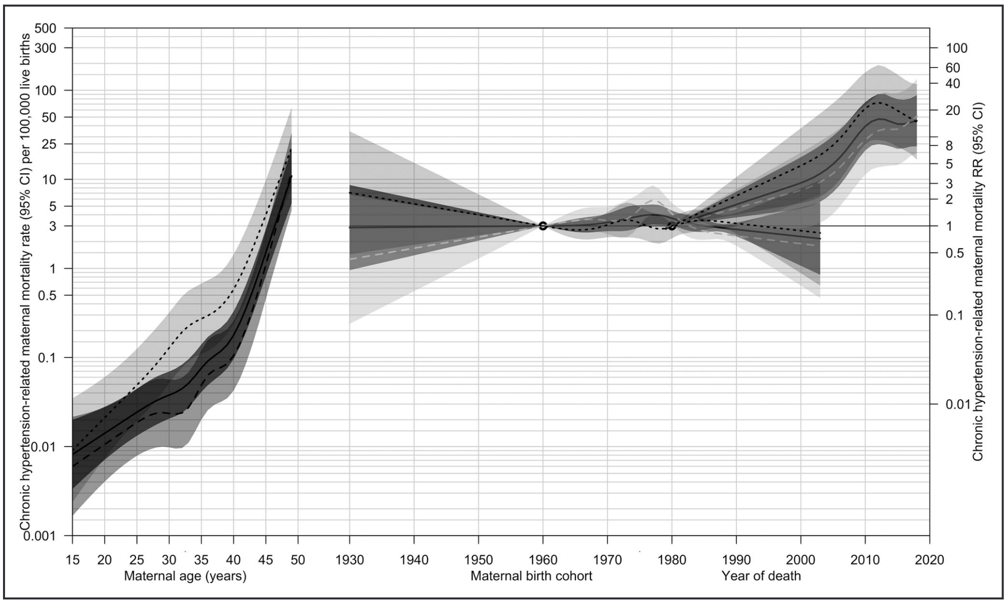

Figure 3. Age-period-cohort trends in overall and race-specific maternal mortality with chronic hypertension as the cause in the United States, 1979 to 2018. Maternal mortality rate (MMR; per 100 000 live births) is shown in relation to maternal age on the *y* axis on the left. The MMR ratio is shown in relation to maternal birth cohort (with the 1960 maternal birth year as the reference) and period (with 1980 as the reference) on the right axis. The shaded bands denote 95% CI. The yearly change in MMR was 9.2% (95% CI, 7.9–10.6) for all women (solid line), 9.4% (95% CI, 7.4–11.4) for White women (dashed line), and 9.1%

(95% CI, 7.1–11.1) for Black women (dotted line). Chronic hypertension–related MMR showed a sharp linear increase with advancing maternal age, with MMRs being higher among Black women compared with White women. Compared with 1980, MMR increased by 9.4% and 9.1% per year among White and Black women, respectively. These analyses showed no appreciable effects due to maternal birth cohorts. RR indicates rate ratio.

Multilevel models that included cohort-specific obesity rates did not converge and were dropped from further consideration. Multilevel models showed that period changes in hypertension-related MMR remained unaffected by period-specific increase in obesity rates (RR, 1.00 [95% CI, 0.99–1.01]; Figure S3). However, the period change in preeclampsia/eclampsia-related MMR (RR, 0.96 [95% CI, 0.95–0.97]) was attenuated after adjustment for period-specific increase in obesity rates MMR (Figure S4). In other words, the observed period effect showing a 66% decline in preeclampsia/eclampsia-related MMR between 1980 and 2018 (RR, 0.34 [95% CI, 0.28–0.42]; Table S3) was reduced to a 4% decline (RR, 0.96 [95% CI, 0.95–0.97]) after adjusting for increasing obesity rates over the same period. Models for chronic hypertension–related MMR did not converge.

Sensitivity Analysis for Misclassification Bias

The probabilistic bias analysis to evaluate potential misclassification of maternal deaths indicated that the overall period-specific RRs for MMR in 2018 compared with 1980 were 0.73 (95% CI, 0.18–3.21) for any hypertension and 0.14 (95% CI, 0.03–0.27) for preeclampsia/eclampsia. For chronic hypertension–related MMRs, the RR for chronic hypertension–specific MMRs comparing 2018 with 1980 (reference) was 20.66 (95% CI, 16.31–25.00) following correction for misclassification.

DISCUSSION

This population-based study, which included all hypertension-related pregnancy–related deaths in the United States over 4 decades, yielded 4 important findings. First, advancing maternal age is associated with a sharp increase in hypertension-related MMR. While effects due to birth cohorts were largely absent, the MMR associated with preeclampsia/eclampsia showed a temporal decline, while that due to chronic hypertension increased. Second, a strong racial disparity in MMR between Black and White women was evident. Third, adjustments for secular changes in rates of obesity appear to have played an important role in shaping the recent temporal changes in hypertension-related MMR, particularly the preeclampsia/eclampsia-related MMR. Fourth, correction for outcome misclassification resulted in stronger period changes in hypertension-related MMR.

Studies have shown temporal increases in the prevalence of chronic hypertension[8] and severe preeclampsia[7] in the United States. Although overall hypertension-related MMRs have been stable during the 40-year study period in this study, chronic hypertension–related MMRs have increased while preeclampsia/eclampsia-associated MMRs have declined. Risk factors for chronic hypertension include advanced maternal age and obesity. As women in the United States have deferred childbirth to a later age,[18] the frequency of pregnancies among women with advanced maternal age, especially women ≥40 years of age, has increased.[19] Advanced age, in turn, is associated with increased risk of chronic hypertension and is an established risk factor for maternal deaths.[20,21]

Obesity rates have surged, reaching the status of an epidemic,[22,23] and is associated with adverse outcomes in all stages of pregnancy,[24–26] from conception to the puerperium. In a meta-analysis, approximately one-quarter of pregnancy complications were attributable to maternal overweight/obesity.[27] It is likely that obesity interacts with advanced maternal age, thereby increasing the prevalence of hypertensive complications.

While the rates of both chronic hypertension[8] and preeclampsia/eclampsia[7] have increased in the United States, there has been a concurrent reduction in MMR due to preeclampsia/eclampsia. The reasons for improving preeclampsia/eclampsia-related MMR are many but likely reflect improved management of blood pressure, use of magnesium sulphate for severe preeclampsia and eclampsia, early recognition of Hemolysis, Elevated Liver enzymes and Low Platelets syndrome, and advances in critical care.[28,29] Preeclampsia/eclampsia management is also associated with increasing rates of planned delivery,[30] which allows for medical optimization and delivery before progression of disease to end organ damage. The steady decline in preeclampsia/eclampsia-related MMR between 1980 and 2018 may reflect large improvements in the management of women with these serious and life-threatening pregnancy complications. The increasing use of low-dose aspirin to prevent preeclampsia[31] among women with risk factors for preeclampsia (chronic hypertension, advanced maternal age, and a body mass index ≥30 kg/m^2) is likely to further accelerate this welcome trend.

In contrast, the optimal management of chronic hypertension in pregnancy remains uncertain. Current strategies involve baseline assessment for subclinical disease, such as renal and cardiac assessments in the first trimester, as well as monitoring for and early recognition of associated complications, such as fetal growth restriction and superimposed preeclampsia.[32] Optimal antepartum blood pressure management remains uncertain as experts continue to debate the risks and benefits of more aggressive antihypertensive management among patients with mild disease.[33] The results of the study underscore the need for improved strategies to actively manage chronic hypertension rather than responding to its profound sequelae.

The evolving changes in the diagnostic criteria for preeclampsia and chronic hypertension, as well as changes in the obstetric management for preeclampsia,[34–38] including decisions to intervene to end the pregnancy to optimize maternal-fetal health, impacted trends in MMR. The finding that adjustment for obesity attenuated the period effect on preeclampsia/eclampsia MMR was unexpected and deserves further scrutiny. It is possible that temporal increases in the early delivery of obese women with preeclampsia played in a role in reducing maternal deaths from preeclampsia/eclampsia.

The disparate trends in chronic hypertension and preeclampsia/eclampsia-related MMRs are noteworthy. Our study showed a 3-fold decline in preeclampsia/eclampsia-related MMR over the 40-year period and a 15-fold increase in MMR associated with chronic hypertension. One reason that may partly explain the large temporal increase in maternal deaths from chronic hypertension is that nonmaternal deaths from chronic hypertension were increasingly being misclassified as maternal deaths due to pregnancy checkbox errors.[38] False positive pregnancy checkbox errors were identified as the cause for the artifactual increase in reported maternal mortality in the United States in recent years.[2–4] A small misclassification in nonmaternal deaths from chronic hypertension could explain the large rise chronic hypertension–related MMR given the relative rarity of maternal deaths from chronic hypertension.[38]

There is growing awareness about the magnitude of medical disparities leading to disproportionate risk of severe maternal morbidity and mortality in the United States.[39–41] This study reinforces the importance of this issue, showing substantially higher hypertension-related

MMR among Black compared with White women. This disparity may reflect social inequities, poor access to care, and other manifestations of systemic racism in the American health care system. The stark disparity in MMR rates by race needs urgent attention.

It is estimated that two-third (63%) of maternal deaths are preventable.[39,42] There have been great efforts to reduce MMR in the United States, including standardizing prenatal care with quality improvement initiatives and implementation of checklists and bundles[43–46]; our study suggests that we are making progress. The overall MMR in the United States in 2018 was 17.4 per 100 000 live births,[2,47] and our study shows that hypertension-related MMR contributed 2.2 maternal deaths per 100 000 live births to this figure. Despite the United Nations Millennium Development Goals to reduce MMR between 1990 and 2015 by 75%, MMR in the United States was essentially unchanged between 1999 and 2017.[4] While the management of preeclampsia/eclampsia has improved substantially, this study also underscores the need to better identify and treat women with chronic hypertension and to target associated risk factors.

Strengths and Limitations of the Study

This APC analysis provides insights that address the extent to which each of these time-related factors influenced temporal changes in MMR. With almost 156 million live births and 3300 maternal deaths with hypertension as the cause, this is perhaps one of the largest studies to date on temporal changes in MMR over the last 4 decades in the United States. Adjustment of MMR trends for period-specific increase in rates of obesity, which appeared to account for the declining preeclampsia/eclampsia-associated MMR, is important. This finding suggests that the steady decline in preeclampsia/eclampsia-related MMR may be, at least partly, related to increasing rates of obesity observed during the study period.

A few important limitations of the study merit discussion. Although recent NCHS reports demonstrate that the pregnancy checkbox resulted in a gross misclassification of maternal deaths, the pregnancy check box did not affect hypertension as a specific cause of death.[2–4] Another limitation includes transition between *ICD, Ninth and Tenth Revision*, coding as well as changes in the diagnostic criteria for preeclampsia. The extent to which the APC effects interact with each other remains unknown. Finally, the National Health and Nutrition Examination Survey data only sample women of Black, White, or Mexican American race/ethnicity, so there is some uncertainty regarding the generalizability of findings that pertain to adjustment for obesity trends. These limitations, however, are unlikely to account for the powerful trends in MMRs associated with hypertensive disorders.

Conclusions

Over the last 4 decades in the United States, deaths due to chronic hypertension increased, whereas deaths due to preeclampsia/eclampsia decreased. The trends in MMR highlight the profound effect of maternal age and obesity in driving the increasing prevalence of chronic hypertension. While management of the most severe complications of preeclampsia/eclampsia has substantially improved, strategies are needed to reduce overall hypertension-related MMRs by targeting improvements in the women's lifecourse,[48,49] such as advanced maternal age, obesity, and racial inequities in care. These issues deserve urgent public health attention.

Perspectives

This large, population-based epidemiological study examines temporal trends in hypertension-related MMRs over 4 decades in the United States. Maternal deaths due to chronic hypertension substantially increased while deaths due to preeclampsia/eclampsia decreased. The study critically underscores the need (1) to develop targeted prenatal interventions, including tight blood pressure control and efforts to reduce body mass index, to ameliorate rates of hypertensive conditions before and during pregnancy and (2) to address the prevailing and concerning race disparity in maternal deaths with hypertension as the cause. The increase in maternal deaths due to chronic hypertension is concerning and deserves careful and immediate attention.

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Novelty and Significance

What Is New?

- During the 40-year period (1979–2018), the overall hypertension-related maternal mortality rate (MMR) was 2.1 per 100 000 live births.
- Yearly hypertension-related MMRs were stable between 1979 and 2018, with MMRs being almost 4-fold higher among Black compared with White women.
- There was a strong age effect with a sharp increase in MMR with advancing age. Maternal birth cohorts were also associated with MMR as women born after 1990 had higher MMR compared with those born in 1960.
- Preeclampsia/eclampsia-related MMRs showed a temporal decline while those due to chronic hypertension increased dramatically. These patterns were similar for Black and White women, although risks were higher for Black women.
- Adjustments for the secular increase in obesity rates appear to attenuate the temporal decline in preeclampsia/eclampsia-related MMR.

What Is Relevant?

- The temporal burden of hypertension-related MMR in the United States has increased substantially for chronic hypertension–associated MMR and decreased for preeclampsia/eclampsia-associated MMR.

- Deaths from preeclampsia/eclampsia continue to contribute significantly to pregnancy-related mortality.

Summary

The recent decline in MMR in the United States was deemed an artifact of increased surveillance. This study shows that the temporal burden of hypertension-related MMRs in the United States has increased substantially for chronic hypertension–associated MMR and decreased for preeclampsia/eclampsia-associated MMR, although deaths from preeclampsia/eclampsia continue to contribute substantially to pregnancy-related deaths. While we are better at managing the most severe complications of preeclampsia/eclampsia, strategies to reduce overall hypertension-related MMR should target improvements in the women's lifecourse, such as advanced maternal age, obesity, and racial inequities in care.