Original Research

Trends in Pregnancy-Related Mortality in the United States

Pregnancy Mortality Surveillance System, 2005–2024

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OBJECTIVE: To describe Pregnancy Mortality Surveillance System (PMSS)–identified underlying causes of pregnancy-related deaths and changes over time in the overall and cause-specific pregnancy-related mortality ratios in the United States, 2005–2024.

METHODS: For this descriptive study, all pregnancy-related deaths were identified in the Centers for Disease Control and Prevention's PMSS from 2005 to 2024. The PMSS has nine mutually exclusive underlying cause-of-death categories: hemorrhage, infection or sepsis, amniotic fluid embolism, thrombotic pulmonary or other embolisms, hypertensive disorders of pregnancy, anesthesia complications, cerebrovascular accidents, cardiovascular conditions (including cardiomyopathy), and other noncardiovascular medical conditions. Beginning with 2020 data, a new cause-of-death code specific for coronavirus disease 2019 (COVID-19) was added to the infection or sepsis category. Cause-specific proportionate mortality was calculated overall and in 5-year intervals. In addition, trends in pregnancy-related mortality ratios, overall and by underlying cause of death, were assessed over time with Joinpoint regression. Joinpoint analysis identified statistically significant changes in trends (joinpoints) and in annual percent change (APC) across distinct time periods.

RESULTS: During 2005–2024, 14,310 pregnancy-related deaths were identified in PMSS. There was a significant increase in the overall pregnancy-related mortality ratio from 2018 to 2021 (APC 20.11, $P<.001$) and a significant decrease from 2021 to 2024 (APC −17.91, $P<.001$). Throughout the study period, the most prevalent causes of death were infection or sepsis, cardiovascular conditions (including cardiomyopathy), other noncardiovascular medical conditions, and hemorrhage. Cardiovascular conditions were the leading cause of death for 17 of the 20 years. Trends in cause-specific pregnancy-related mortality ratios differed by cause of death. Deaths resulting from infection or sepsis had the largest increase in 2018–2021 (APC 86.17, $P<.001$) and the largest decrease in 2021–2024 (APC −49.67, $P<.001$), which coincided with the timing of the COVID-19 pandemic. Hemorrhage deaths showed an increasing pregnancy-related mortality ratio from 2017 to 2024 (APC 6.84, $P=.02$). The pregnancy-related mortality ratio for other cardiovascular conditions decreased from 2020 to 2024 (APC −9.49, $P=.04$).

CONCLUSION: From 2005 to 2024, the most prevalent causes of pregnancy-related death were cardiovascular conditions, infection or sepsis, other noncardiovascular medical conditions, and hemorrhage. However, cause-specific trends in pregnancy-related mortality in the United States have changed over time. These differences underscore the importance of sustained surveillance to better inform clinical and public health efforts to address leading and emerging causes of pregnancy-related death.

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The Centers for Disease Control and Prevention's (CDC's) Pregnancy Mortality Surveillance System (PMSS) began reporting the pregnancy-related mortality ratio (number of reported pregnancy-related deaths/100,000 live births) in the United States in 1987. A death is determined to be pregnancy related if it occurs during or within 1 year of the end of pregnancy from any cause related to or aggravated by the pregnancy.[1]

Past examination of trends in the proportions of underlying causes of pregnancy-related mortality suggested an increasing contribution of cardiovascular and other noncardiovascular medical conditions and a reduction in the contribution of traditional obstetric causes such as hypertensive disorders of pregnancy.[2] A limitation of proportionate mortality is that a high cause-specific mortality rate in a specific category can reduce the proportionate mortality for all the other causes. Cause-specific pregnancy-related mortality ratios provide a more reliable measure for assessing change in population-based risk within a category over time.

Our objective was to describe PMSS-identified underlying causes of pregnancy-related deaths and the changes over time in the overall and cause-specific pregnancy-related mortality ratios in the United States during 2005 through 2024.

METHODS

We used PMSS data from pregnancy-related deaths occurring during 2005 through 2024. The PMSS methodology is well described online.[1] Briefly, the CDC Division of Reproductive Health requested all states; Washington, DC; New York City; Puerto Rico (beginning 2020); and the Northern Mariana Islands (beginning 2021) to voluntarily send death records, linked live-birth or fetal death records if applicable, and additional available data on deaths that occurred during pregnancy or within 1 year of the end of pregnancy. Medical epidemiologists with clinical obstetrics training reviewed the available information to determine whether each death was pregnancy-related and assigned each pregnancy-related death a PMSS-identified cause of death.

The PMSS has nine mutually exclusive underlying cause-of-death categories: hemorrhage, infection or sepsis, amniotic fluid embolism, thrombotic pulmonary or other embolisms, hypertensive disorders of pregnancy, anesthesia complications, cerebrovascular accidents, cardiovascular conditions (including cardiomyopathy), and other noncardiovascular medical conditions. Beginning with 2020 data, a new cause-of-death code specific for coronavirus disease (COVID-19) was added to the infection or sepsis category. With 2024 data, PMSS began grouping cardiomyopathy and other cardiovascular conditions together under the broader cardiovascular conditions category.[1] In this publication, we analyze the cardiovascular conditions as a single category and then assess cardiomyopathy and other cardiovascular conditions separately to examine differences in trends.

Pregnancy-related mortality ratios were calculated as the number of pregnancy-related deaths per 100,000 live births overall and by cause of death and year. Birth data used for denominators to calculate pregnancy-related mortality ratios were obtained from U.S. natality files from the National Vital Statistics System, 2005–2024.[3] Pregnancy-related deaths and live births occurring within 50 U.S. states; New York City; Washington, DC; Puerto Rico (beginning with 2020 data); and the Northern Mariana Islands (beginning with 2021 data) among residents of those jurisdictions were included. Data were not available for inclusion in PMSS from Washington, DC, in 2023 and 2024 and from North Dakota and South Dakota in 2024 and were not included in either the numerator or denominator.

We calculated proportionate mortality (the specific cause of death as a percentage of all pregnancy-related deaths) overall and by 5-year intervals using SAS 9.4. We did not calculate pregnancy-related mortality ratios when the cause of death was unknown (5.8% of deaths). We assessed trends over time in pregnancy-related mortality ratios overall and by underlying cause of death using Joinpoint Regression Software version 5.4.0.0. We selected the best-fit regression model based on the weighted Bayesian information criteria to identify statistically significant ($P<.05$) changes in trends, or joinpoints, and annual percent change (APC) with 95% CIs for distinct time periods. We modeled rates on the log scale with Poisson variance selected for the heteroscedastic errors option. A minimum of two observations was required for joinpoint segments, and a maximum of three joinpoints was selected for the models.

Pregnancy-related mortality ratios were not calculated when there were fewer than eight pregnancy-related deaths because pregnancy-related mortality ratios based on fewer than eight deaths are considered unreliable for reporting.[1] This activity was reviewed by the CDC, deemed not human subjects research, and conducted consistent with applicable federal law and CDC policy (eg, 45 C.F.R. part 46, 21 C.F.R. part 56; 42 U.S.C. Sect. 241[d]; 5 U.S.C. Sect. 552a; 44 U.S.C. Sect. 3501 et seq).

RESULTS

A total of 14,310 pregnancy-related deaths were identified during 2005–2024. The overall pregnancy-related mortality ratio peaked in 2021 (33.17 pregnancy-related deaths/100,000 live births) and was lowest in 2007 (14.50) (Fig. 1). Two significant joinpoints were identified in pregnancy-related mortality ratios during 2005–2024, an increase from 2018 to 2021 (APC 20.11, 95% CI, 10.10–25.36, $P<.001$) followed by a decrease from 2021 to 2024 (APC −17.91, 95% CI, −25.21 to −12.54, $P<.001$).

Among deaths occurring during 2005–2024, the four most frequent causes of death were cardiovascular conditions (24.3% total, 10.6% cardiomyopathy), infection or sepsis (17.8% total, 12.8% excluding COVID-19), other noncardiovascular medical conditions (12.2%), and hemorrhage (11.5%) (Fig. 2). Proportionate cause-specific mortality overall and for each year is presented in Appendix 1 (available online at https://links.lww.com/AOG/E781). Deaths resulting from cardiovascular conditions were the leading cause of death for 17 of the 20 years.

Cause-specific proportionate mortality in 5-year intervals during 2005–2024 is shown in Figure 3. The cardiovascular conditions category was the most frequent cause of death in all intervals except 2020–2024 and ranged from 25.6% to 27.6% of all pregnancy-related deaths during 2005–2019. The proportion of deaths resulting from infection or sepsis in 2020–2024 was 28.7%, more than double the proportion for previous year groupings, an increase driven primarily by COVID-19. Deaths caused by COVID-

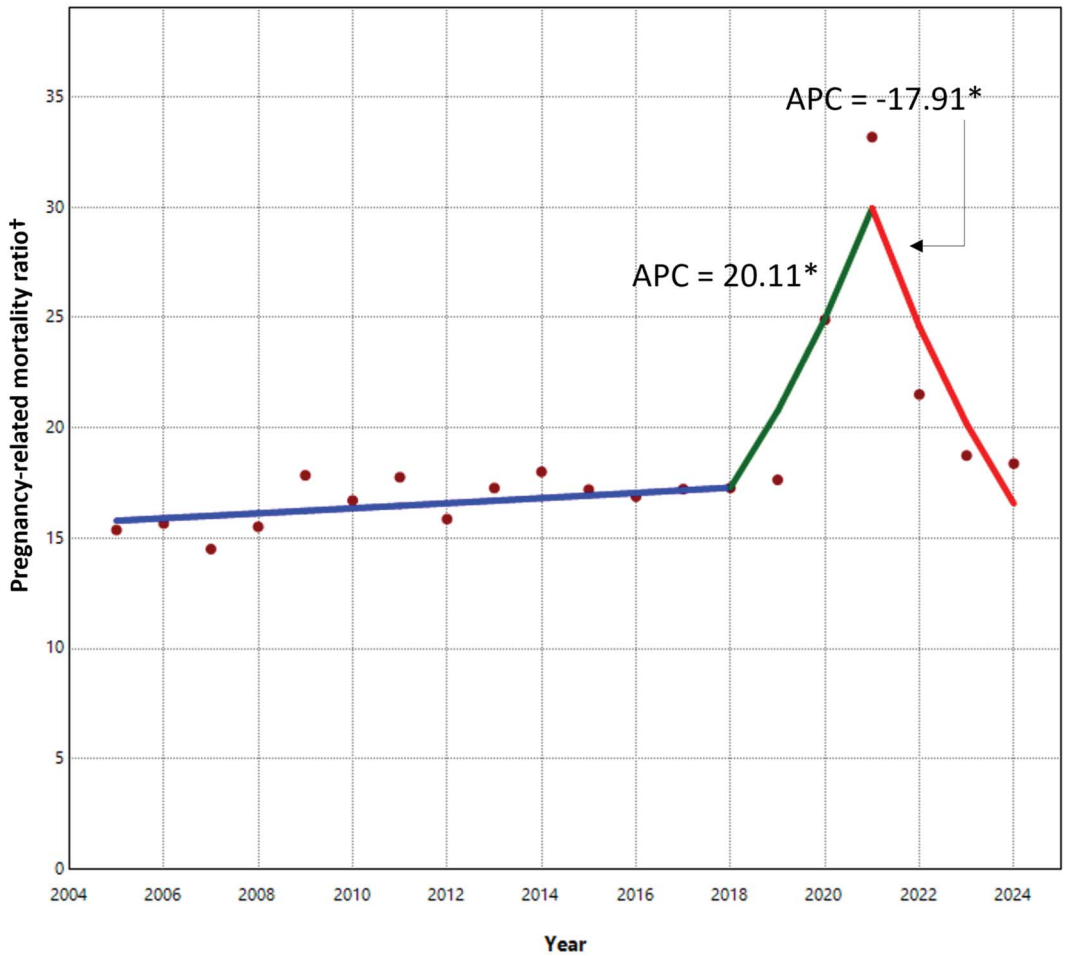

Fig. 1. Joinpoint regression analysis of pregnancy-related mortality ratios, Pregnancy Mortality Surveillance System, United States, 2005–2024. *Annual percent change (APC) is significantly different from 0 at $\alpha<.05$. †Pregnancy-related mortality ratio is expressed as the number of pregnancy-related deaths per 100,000 live births. Changes in *line segment color* indicate joinpoints.

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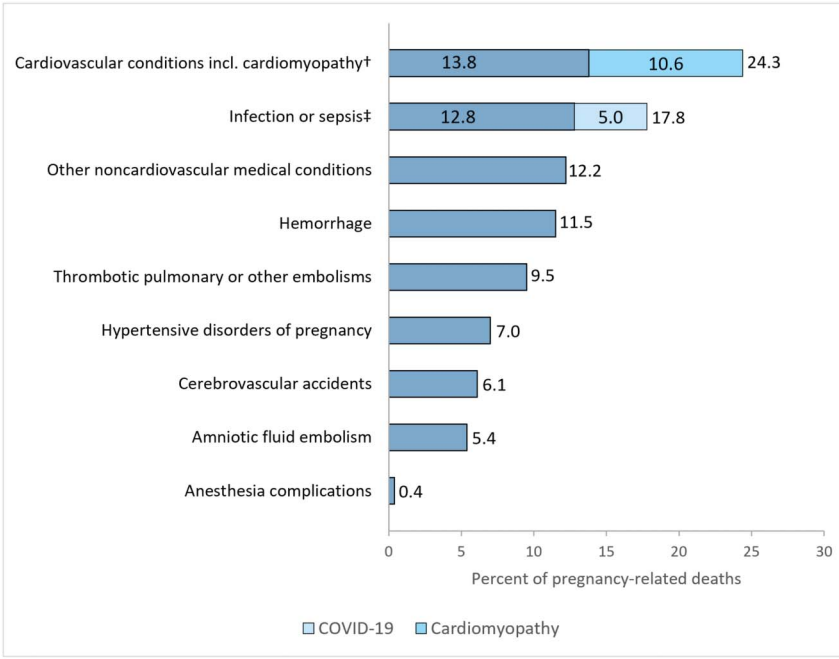

Fig. 2. Distribution of pregnancy-related deaths by underlying cause of death, Pregnancy Mortality Surveillance System, United States, 2005–2024. *Percentages may not equal to 100% because of rounding. *Cause-of-death categories are mutually exclusive. †The cardiovascular conditions category includes deaths with underlying causes of cardiomyopathy and other cardiovascular conditions. The proportions of cardiomyopathy and other cardiovascular conditions deaths are provided separately. ‡Beginning with 2020 data, a new cause-of-death code specific for coronavirus disease 2019 (COVID-19) was added to the infection or sepsis category. The proportion of deaths attributable to COVID-19 is provided. This figure excludes deaths for which the cause of death was unknown (5.8% of all 2005–2024 pregnancy-related deaths).

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19 accounted for 58.8% of infection or sepsis deaths in 2020–2024.

Trends in cause-specific pregnancy-related mortality ratios varied by cause (Fig. 4). The pregnancy-related mortality ratio for infection or sepsis was stable from 2005 to 2018 (APC 0.00, 95% CI, −6.38 to 4.30, P=.84); from 2018 to 2021, there was a steep increase (APC 86.17, 95% CI, 48.68–119.17, P<.001) and then a decrease from 2021 to 2024 (APC −49.67, 95% CI, −62.19 to −38.74, P<.001) to near the 2018 value. The pregnancy-related mortality ratio decreased for hypertensive disorders of pregnancy from 2005 to 2019 (APC −3.29, 95% CI, −9.72 to −1.85, P=.02) followed by a nonsignificant increase in the pregnancy-related mortality ratio from 2019 to 2024 (APC 5.49, 95% CI, −1.40 to 24.87, P=.16). Hemorrhage was stable from 2005 to 2017 (APC 1.10, 95% CI, −8.93 to 3.18, P=.66) and then increased from 2017 to 2024 (APC 6.84, 95% CI, 3.01–21.32, P=.02). The pregnancy-related mortality ratio increased from 2005 to 2020 for cardiovascular conditions (APC 1.33, 95% CI, 0.48–4.50, P=.006) and then decreased from 2020 to 2024 (APC −6.07, 95% CI, −19.47 to −0.45, P=.02). The pregnancy-related mortality ratio increased from 2005 to 2020 for other cardiovascular conditions (APC 1.90, 95% CI, 0.52–10.97, P=.02) and decreased from 2020 to 2024 (APC −9.49, 95% CI, −33.40 to −0.34, P=.04); there was no change in the pregnancy-related mortality ratio for cardiomyopathy over the study period. The pregnancy-related mortality ratio for cerebrovascular accidents increased from 2005 to 2014 (APC 6.15, 95% CI, 1.55–25.37, P=.007) and then decreased from 2014 to 2024 (APC −4.92, 95% CI, −25.59 to −1.24, P=.01). The pregnancy-related mortality ratio increased over the study period for thrombotic pulmonary or other embolisms (APC 1.95, 95% CI, 0.52–3.49, P=.008). The pregnancy-related mortality ratio for amniotic fluid embolism increased from 2005 to 2024 (APC 1.44, 95% CI, 0.04–2.85, P=.046). Annual cause-specific pregnancy-related mortality ratios, including pregnancy-related mortality ratios for deaths resulting from infection or sepsis excluding COVID-19 deaths, are provided in Appendix 2 (available online at https://links.lww.com/AOG/E781).

DISCUSSION

This study highlights trends in pregnancy-related mortality in the United States during 2005–2024 by examining proportionate mortality to identify the most frequent underlying causes of death and cause-specific pregnancy-related mortality ratios to understand trends in cause-specific population-level risk. From 2005 to 2024, the most prevalent causes of death were cardiovascular conditions, infection or sepsis, other noncardiovascular medical conditions, and hemorrhage. After a long period of stability, the

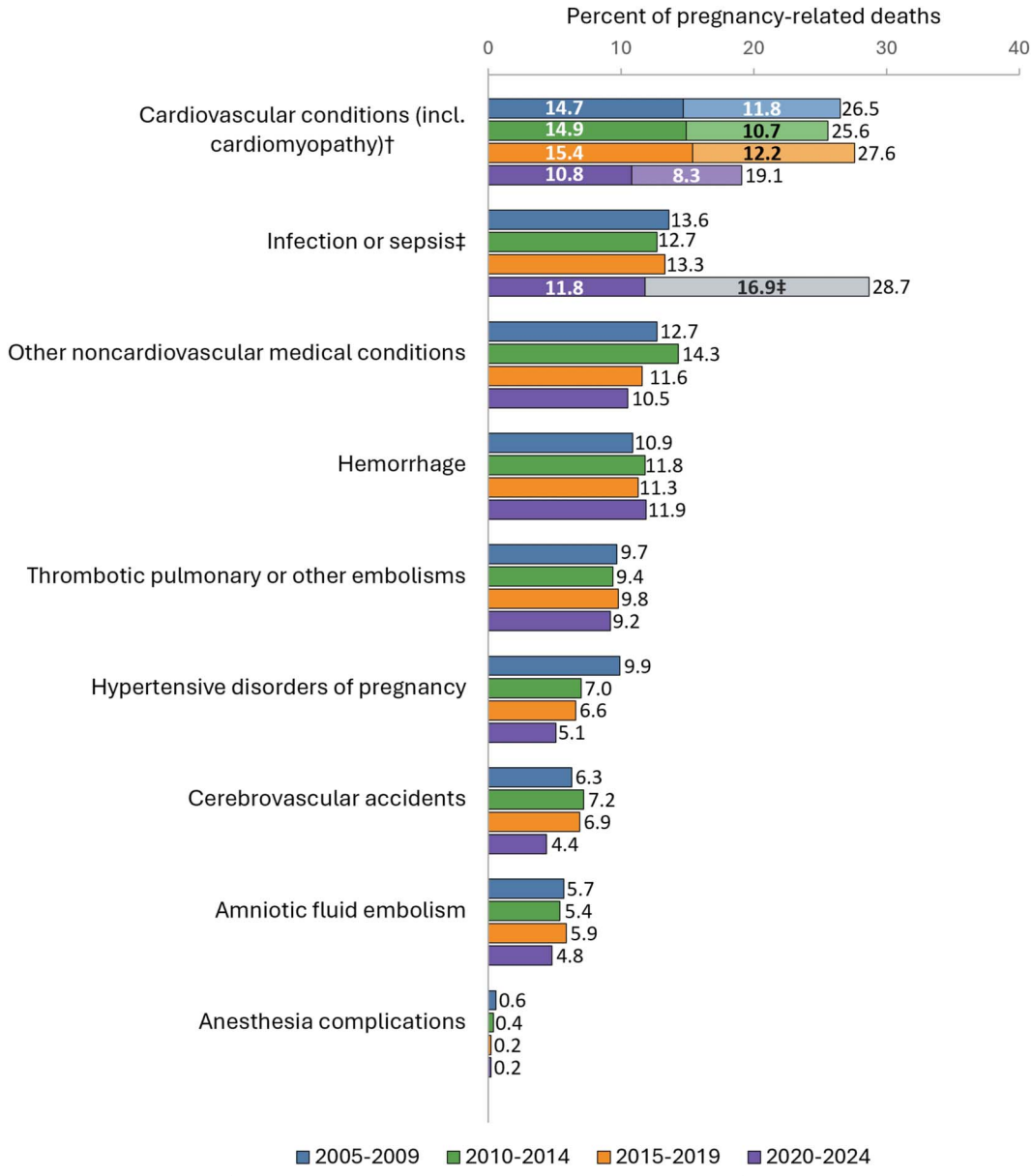

Fig. 3. Distribution of pregnancy-related deaths by underlying cause of death in 5-year intervals, Pregnancy Mortality Surveillance System, United States, 2005–2024.* Percentages may not equal to 100% because of rounding. *Cause-of-death categories are mutually exclusive. †The cardiovascular conditions category includes deaths with underlying causes of cardiomyopathy and other cardiovascular conditions. The proportions of both cardiomyopathy (*light shading*) and other cardiovascular deaths (*dark shading*) are provided separately for each year grouping. ‡Beginning with 2020 data, a new cause-of-death code specific for coronavirus disease 2019 (COVID-19) was added to the infection or sepsis category. The 2020–2024 infection or sepsis category includes COVID-19 deaths as a proportion of all 2020–2024 pregnancy-related deaths (*gray shading*). This figure excludes deaths for which the cause of death was unknown (5.8% of all 2005–2024 pregnancy-related deaths).

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pregnancy-related mortality ratio increased significantly from 2018 to 2021, driven largely by a rise in deaths from infection or sepsis during the COVID-19 pandemic. The pregnancy-related mortality ratio declined rapidly and returned to prepandemic levels by 2024. There were significant changes in cause-specific pregnancy-related mortality ratios over the study period.

The cardiovascular conditions categories (cardiomyopathy and other cardiovascular conditions)

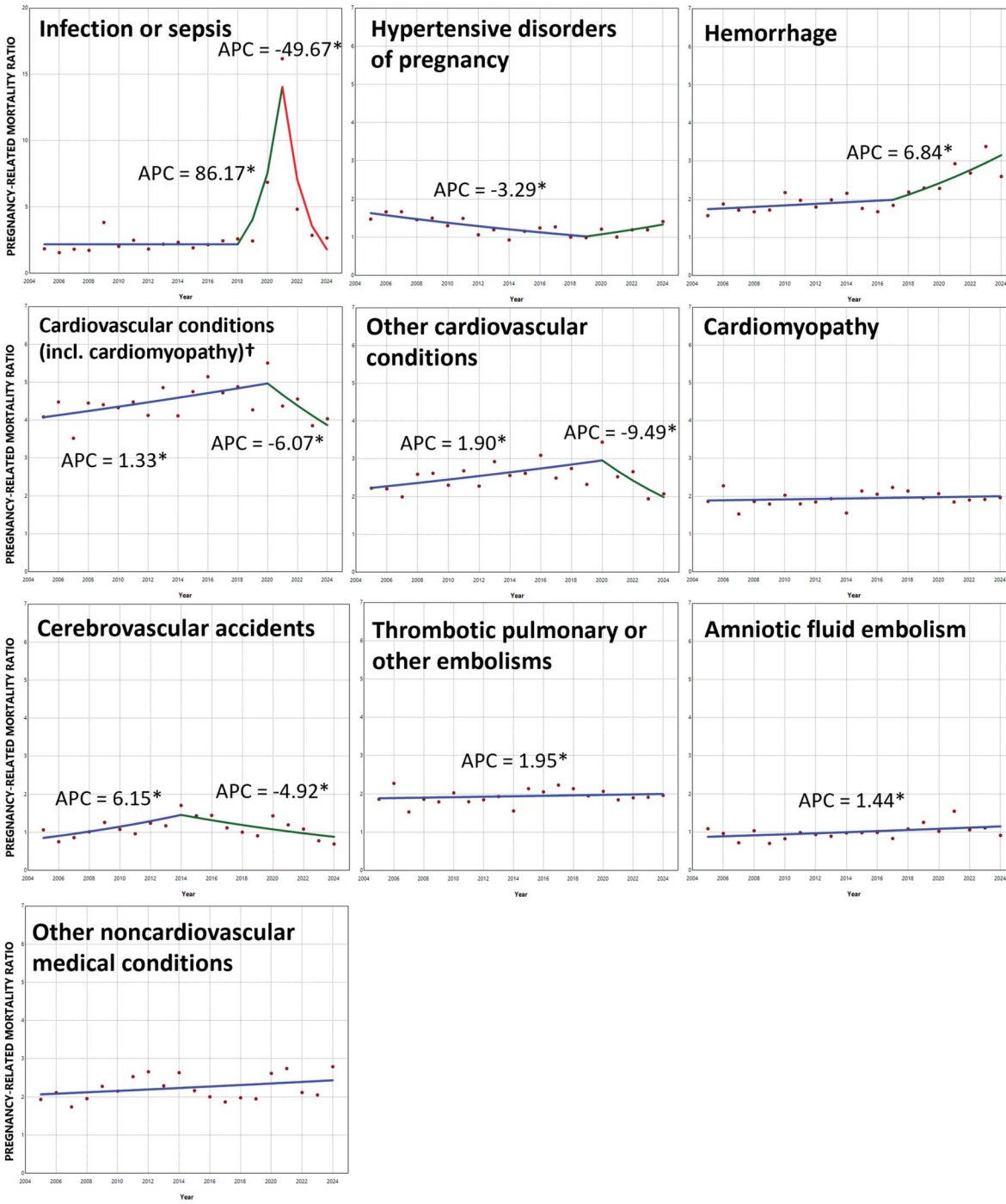

Fig. 4. Joinpoint regression analysis of pregnancy-related mortality ratios (PRMRs) by cause of death, Pregnancy Mortality Surveillance System, United States, 2005–2024. The Y axis scale differs for the infection or sepsis category. Annual percent change (APC) is not shown for regression segments with $P>.05$. *The APC is significantly different from 0 at $\alpha<.05$. †The cardiovascular conditions category includes deaths with underlying causes of cardiomyopathy and other cardiovascular conditions. Joinpoint trend analysis for deaths attributable to cardiomyopathy and other cardiovascular conditions is provided separately. The PRMRs (number of pregnancy-related deaths/100,000 live births) were not calculated for deaths resulting from anesthesia complications for all years except 2009, because PRMRs based on fewer than eight deaths are considered unreliable for reporting. This figure excludes deaths for which the cause of death was unknown. Changes in *line segment color* indicate joinpoints.

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accounted for one in four pregnancy-related deaths. The contribution of cardiovascular conditions to pregnancy-related mortality in the United States is consistent with findings from surveillance systems using similar enhanced methods across eight European countries.[4] In that analysis, cardiovascular disease was a major contributor to maternal mortality, whether measured within 42 days or 43 days to 1 year after the end of pregnancy.[4] Although the pregnancy-related mortality ratio for cardiomyopathy was stable over the study period, both pregnancy-related mortality ratios for other cardiovascular conditions and cerebrovascular accidents showed declining rates after periods of increase. Ongoing surveillance and additional analyses are needed to better understand the factors contributing to the reduction in pregnancy-related mortality ratios.

Infection or sepsis accounted for the second largest proportion of pregnancy-related deaths in 2005–2024. After COVID-19 was excluded, infection was the third leading cause in 2020–2024 and has been a frequent cause throughout the 20-year study period. Data from maternal mortality review committees identified opportunities to improve outcomes, including earlier recognition and treatment of pelvic and nonpelvic infections.[5]

The other noncardiovascular medical conditions category was the third most frequent cause of death and includes many chronic conditions such as asthma, diabetes mellitus, and epilepsy. An analysis of this category in the 2012–2022 PMSS data found epilepsy to be the most frequent subcategory.[6] The MBRRACE-UK (Mothers and Babies: Reducing Risk Through Audits and Confidential Enquiries Across the UK) report in 2020 similarly identified epilepsy as a leading cause of pregnancy-related mortality in the United Kingdom, with an increase in deaths resulting specifically from sudden unexpected death in epilepsy.[7]

We observed a gradual increase in the thrombotic pulmonary or other embolisms pregnancy-related mortality ratio throughout the study period. This increase in thrombotic pulmonary or other embolisms is consistent with the findings in the MBRRACE-UK analysis.[8] Hypertensive disorders of pregnancy accounted for 7.0% of the pregnancy-related deaths in 2005–2024. The pregnancy-related mortality ratio declined from 2005 until 2019. However, the recent change in trend warrants ongoing monitoring.

The hemorrhage pregnancy-related mortality ratio remained stable until 2017 and then increased significantly through 2024. A recent analysis of pregnancy-related hemorrhage mortality from 2012 to 2019 identified that ruptured ectopic, postpartum hemorrhage, and placenta accreta spectrum were the most frequent causes of hemorrhage-related mortality.[9] However, although the analysis did not find statistically significant trends in subclassifications, it was limited by the relatively small numbers of deaths in each subclassification and did not include the same years of data as the present analysis. The increase in pregnancy-related hemorrhage deaths underscores the importance of continued surveillance to understand the change.

This analysis has several limitations. The PMSS data are limited by the completeness and accuracy of original records, potentially leading to misclassification of pregnancy-related deaths; however, PMSS case identification and clinical review processes minimize misclassification.[10] Generally, pregnancy-relatedness cannot be determined in PMSS for injury deaths (eg, drug overdoses, suicides, homicides) or for cancer-related deaths because of limited information about death circumstances.[11] Therefore, these deaths are often not included in the pregnancy-related mortality ratio. Jurisdictional participation in PMSS shifted in later years. Nonparticipating jurisdictions in 2023 and 2024 represented 0.1–1.3% of deaths annually during 2005–2022, and the two jurisdictions that began participating during the last 5 years represented 1.2% of deaths in 2020–2024 and 0.3% of deaths overall, suggesting that differences in participation had minimal effects on overall results. Strengths of the analysis include the collection of data from all jurisdictions for most years and application of consistent coding across jurisdictions and over time, which enables PMSS to assess changes in the underlying cause of death.

This analysis of PMSS data provides timely information about cause-specific differences in trends in underlying causes of pregnancy-related mortality. These differences underscore the importance of sustained surveillance for changes in pregnancy-related mortality that may help align research, quality improvement initiatives, and public health efforts to prevent leading and emerging causes of pregnancy-related death.

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