

Surgical Anastomosis, Bypass, or Graft–Related Mortality: Temporal Trends and Demographic Disparities in the United States, 1999–2024

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Abstract

Background

Surgical operations involving anastomosis, bypass, or graft are performed across several specialties, but national mortality patterns associated with later complications of these procedures have not been well described. This study examined long-term trends and demographic and geographic differences in mortality recorded under International Classification of Diseases, Tenth Revision code Y83.2 in the United States.

Methods

Death-certificate data for adults aged 25 years or older were obtained from the CDC WONDER Multiple Cause of Death database for 1999–2024. Age-adjusted mortality rates (AAMRs) were calculated per 100,000 population and standardized to the 2000 U.S. population. Joinpoint regression was used to estimate annual percent changes (APCs) and average annual percent changes (AAPCs). Analyses were performed overall and by sex, race and ethnicity, census region, urbanization status, state, and place of death. Urbanization data were available through 2020.

Results

The annual overall extract included 87,980 deaths. The AAMR declined from 2.744 in 1999 to 0.872 in 2015 (APC, – 7.56%; 95% CI, – 8.38% to – 6.72%), increased to 2.021 in 2020 (APC, 22.30%; 95% CI, 13.79% to 31.46%), and then declined to 0.713 in 2024 (APC, – 25.80%; 95% CI, – 31.25% to – 19.92%). The overall AAPC was – 5.61% (95% CI, – 7.34% to – 3.86%). Males had higher AAMRs than females throughout the study period. Non-Hispanic (NH) Black individuals had the smallest long-term racial and ethnic decline and the highest AAMR in 2024. Nonmetropolitan areas had higher AAMRs than metropolitan areas during 1999–2020. The West experienced the steepest temporary regional increase, and Mississippi had the highest pooled state-level AAMR.

Conclusion

Mortality associated with surgical operations involving anastomosis, bypass, or graft declined significantly between 1999 and 2024, although the long-term improvement was interrupted by a marked increase beginning in the mid-to-late 2010s. Persistent differences across demographic and geographic groups indicate that the mortality burden was not distributed evenly.

Introduction

Surgical procedures involving anastomosis, bypass, or graft formation are used throughout cardiovascular, vascular, gastrointestinal, transplant, and reconstructive surgery. These operations restore continuity between anatomical structures, redirect blood flow around an obstruction, or replace damaged tissue. Although they are often lifesaving, later complications may include anastomotic leakage, thrombosis, occlusion, infection, hemorrhage, dehiscence, and graft failure. Severe complications can require reoperation, prolong hospitalization, cause organ dysfunction, and increase the risk of death (1–3). International Classification of Diseases, Tenth Revision code Y83.2 identifies a surgical operation involving an anastomosis, bypass, or graft as the cause of an abnormal reaction or later complication, without mention of misadventure at the time of the procedure (4).

Perioperative and postoperative care has changed considerably over recent decades. Improvements in patient selection, anesthesia, infection prevention, intensive care, postoperative surveillance, and multidisciplinary management have increased the ability of surgical teams to prevent and treat complications. Enhanced Recovery After Surgery pathways have also standardized elements of perioperative preparation, analgesia, nutrition, mobilization, and discharge planning (2,5). Randomized evidence has linked these pathways with fewer complications and shorter hospital stays, although a statistically significant reduction in mortality has not been established (2). Outcomes after major complications also depend on timely recognition and the ability of hospitals to rescue deteriorating patients, while procedural volume and institutional experience may affect mortality after complex operations (3,6).

The benefits of progress in surgical care may not be distributed equally. Sex-based differences have been reported after noncardiac and vascular surgery (7,23). Racial and ethnic disparities have also been described in access to surgical treatment, utilization of major procedures, hospital quality, and postoperative outcomes (8–10). These differences may reflect interactions among comorbidity burden, socioeconomic conditions, insurance coverage, referral patterns, hospital resources, and access to specialist services. Geographic barriers are especially relevant for people living in rural areas, where longer travel distances, workforce shortages, transfer delays, and limited access to tertiary surgical and rehabilitation services may influence outcomes (11).

Most published studies have focused on individual procedures, selected postoperative complications, or short-term outcomes. National evidence describing long-term mortality associated with the broader Y83.2 category across demographic and geographic populations remains limited. Accordingly, we used the CDC WONDER Multiple Cause of Death database to examine mortality associated with surgical operations involving anastomosis, bypass, or graft among U.S. adults aged 25 years or older from 1999 to 2024. Temporal trends were assessed overall and by sex, race and ethnicity, census region, and urbanization status, while state-level mortality and place of death were also evaluated.

Methods

The data was acquired through multiple cause of death files of the Centers for Disease Control and Prevention Wide-Ranging Online Data of Epidemiologic Research (CDC WONDER) from 1999–2024 [12]. Multiple causes of death files were used to extract deaths related to Surgical operation with anastomosis, bypass, or graft as the cause of later complications in adults aged ≥ 25 years. These diseases were identified using the International Classification of Diseases, Tenth Revision (ICD-10). Surgical operation with anastomosis, bypass, or graft as the cause of later complications was defined using code Y83.2.

The research utilized only de-identified and publicly accessible data and thus did not require review by the Institutional Review Board. The observational study was documented in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [13].

Data Extraction:

Data were obtained for the whole adult population, disaggregated in relation to sex, ten-year age bracket (25–74 through ≥ 85), race/ethnicity, and U.S. urbanization (metropolitan/non-metropolitan), the state the person lived in, as well as where the person died. Race and ethnicity started to be documented based on the information reported by the funeral directors and by the next of kin. The race/ethnic composition was categorized into Hispanic (Latino) and non-Hispanic (NH), where the latter was divided into NH Black, NH White and a combined group (American Indians and Asians or Pacific Islanders) as NH Other. This combination of races classified as NH Other subgroup was used to avoid unreliable estimates due to low death counts. According to the United States Census Bureau, the United States had four regions, namely Northeast, Midwest, South and West [14]. The level of urbanization was operationalized with the help of the Urban-Rural Classification Scheme of the National Center of Health Statistics (NCHS), 2013[15]. Counties that had a population of 50,000 or higher were metropolitan; the others were non-metropolitan.

Statistical Analysis:

The CDC WONDER provided annual mortality rates and population data. The direct method of calculating AAMRs was applied, and AAMRs were standardized to the 2000 U.S. standard population[16]. The rates of AAMRs were calculated per 100,000 of the population, and 95% confidence intervals were estimated on the assumption of the Poisson distribution[17]. AAMRs were used to measure race/ethnicity, gender, census region, state, age group, and urban-rural classification mortality trends.

Temporal trends were also evaluated with the help of the joinpoint regression relying on the log-linear models that yielded estimates of the Annual Percent Change (APC) values in individual segments and the Average Annual Percent Change (AAPC) value of the entire study period. The 95% confidence intervals for APC and AAPC were calculated using the parametric method implemented in the Joinpoint Regression software, along with permutation tests to determine the statistical significance of joinpoints. The analyses were carried out with the National Cancer Institute's Joinpoint Regression software (version 5.4.0)[18]. APC/AAPCs/Tau CIs were calculated by using a parametric method.

The empirically chosen best model fit determined the number and location of joinpoints. A p-value < 0.05 was considered significant. Each segment was reported with APCs and respective 95% CIs.

RESULTS

During the entire study period, a total of 87,980 deaths were reported among the patients with complications of graft or bypass after surgery in United States. The majority of deaths occurred in medical facilities as inpatients, accounting for 79.55% (n=69,991) of all deaths. A considerable proportion of deaths occurred at the decedent's home, representing 12.11% (n=10,649), while nursing homes or long-term care facilities contributed 4.31% (n=3,795) of total deaths. Hospice facilities accounted for 1.98% (n=1,738), whereas other locations made up 1.82% (n=1,600). The place of death was unknown for a minimal fraction of cases (0.24%, n=207). (Supplementary Table 1)

ANNUAL TRENDS

A declining overall mortality trend was observed across the study period. The AAMR decreased sharply from 2.744 per 100,000 in 1999 to 0.872 in 2015 (APC = -7.5578*; 95% CI: -8.3843 to -6.7239), followed by a marked increase to 2.021 in 2020 (APC = 22.3031*; 95% CI: 13.7856 to 31.458), and then declined sharply again to 0.713 in 2024 (APC = -25.8009*; 95% CI: -31.2534 to -19.9159). The overall long-term trend from 1999–2024 remained statistically significant, with an AAPC of -5.6139* (95% CI: -7.3382 to -3.8575). Figure 1 (Supplementary Table 2)

AAMR STRATIFIED BY SEX

Females exhibited lower mortality than males throughout the study period, with a significant long-term decline. The AAMR decreased from 2.014 per 100,000 in 1999 to 0.671 in 2014 (APC = -7.5528*; 95% CI: -8.3233 to -6.7758), then rose to 1.287 in 2021 (APC = 10.0279*; 95% CI: 6.1703 to 14.0256), and subsequently declined sharply to 0.525 by 2024 (APC = -30.2846*; 95% CI: -38.169 to -21.3948). The overall long-term trend was statistically significant, with an AAPC of -6.1668* (95% CI: -7.7495 to -4.557).

Males had consistently higher mortality rates than females, with the AAMR decreasing from 3.705 per 100,000 in 1999 to 1.131 in 2015 (APC = -7.4008*; 95% CI: -8.2466 to -6.5471), rising to 3.153 in 2021 (APC = 20.1422*; 95% CI: 14.4146 to 26.1566), and then declining sharply to 0.949 by 2024 (APC = -39.7073*; 95% CI: -47.0567 to -31.3378).

The long-term trend was statistically significant, with an AAPC of -6.3759* (95% CI: -8.139 to -4.5791). Figure 1. (Supplementary Table 2)

AAMR STRATIFIED BY RACE

The mortality trend for Hispanic or Latino persons showed a declining pattern, with the AAMR decreasing from 1.703 per 100,000 in 1999 to 0.617 in 2015 (APC = -7.5688*; 95% CI: -9.2748 to -5.8307). This was followed by a sharp increase to 1.828 in 2020 (APC = 29.1991*; 95% CI: 15.118 to 45.0025), and then a marked decline to 0.594 by 2024 (APC = -28.2144*; 95% CI: -35.8526 to -19.6667). The long-term trend showed a statistically significant decrease in the AAMR for Hispanic or Latino persons, with an AAPC of -5.0835* (95% CI: -7.8411 to -2.2433).

NH Black or African American individuals demonstrated a similar declining trend, with the AAMR decreasing from 2.661 per 100,000 in 1999 to 1.292 in 2015 (APC = -5.1650*; 95% CI: -6.0119 to -4.3105). This was followed by an increase to 2.411 in 2021 (APC = 9.8158*; 95% CI: 4.7251 to 15.1539), and then a sharp decline to 1.116 by 2024 (APC = -26.4068*; 95% CI: -34.6893 to -17.0739). There was an overall significant decrease when looking longer-term, with an AAPC of -4.7116* (95% CI: -6.4018 to -2.9909).

NH White individuals consistently exhibited the highest mortality burden across all racial groups. The AAMR decreased from 2.789 in 1999 to 0.844 in 2015 (APC = -7.8187*; 95% CI: -8.6803 to -6.9489), followed by a sharp rise to 2.021 in 2020 (APC = 23.1280*; 95% CI: 13.9308 to 33.0677), and then declined sharply to 0.706 by 2024 (APC = -26.3718*; 95% CI: -32.2636 to -19.9675). The overall trend from 1999–2024 showed a significant long-term decrease, with an AAPC of -5.7742* (95% CI: -7.6313 to -3.8798).

NH Other racial groups experienced a comparable pattern of decline. The AAMR decreased from 2.003 in 1999 to 0.735 in 2015 (APC = -7.0839*; 95% CI: -9.0681 to -5.0563), rose sharply to 1.838 in 2020 (APC = 28.5358*; 95% CI: 13.2642 to 45.8664), and then declined sharply to 0.464 in 2024 (APC = -32.0721*; 95% CI: -40.7005 to -22.1882). The long-term trend showed a statistically significant decrease, with an AAPC of -5.7002* (95% CI: -8.8231 to -2.4703). Figure 2. (Supplementary Table 3)

AAMR STRATIFIED BY URBANIZATION

Urban (metropolitan) areas demonstrated a declining trend in mortality, with the AAMR decreasing from 2.59 per 100,000 in 1999 to 0.843 in 2015 (APC = -7.4476*; 95% CI: -8.0963 to -6.7944). This was followed by a sharp increase to 1.946 in 2020 (APC = 20.4972*; 95% CI: 15.9208 to 25.2543). The overall long-term trend was statistically significant, with an AAPC of -1.4468* (95% CI: -2.4182 to -0.4657).

Rural (Non-Metropolitan) areas consistently exhibited higher mortality rates throughout the study period, decreasing from 3.369 in 1999 to 1.153 in 2015 (APC = -7.1662*; 95% CI: -7.888 to -6.4388), followed by a notable rise to 2.48 in 2020 (APC = 19.0902*; 95% CI: 13.865 to 24.5551). The long-term trend was also statistically significant, with an AAPC of -1.4944* (95% CI: -2.6069 to -0.3692). (Figure 3. Supplementary Table 4)

AAMR STRATIFIED BY CENSUS REGION

In all U.S. census regions, AAMR exhibited a general declining pattern through the mid-2010s, followed by a rise around 2019–2021 and a sharp decline thereafter. The Northeast showed a marked decline from 1999 to 2008 (APC = -9.3825*; 95% CI: -10.8618 to -7.8788), a non-significant further decline from 2008 to 2015 (APC = -3.8194; 95% CI: -7.602 to 0.118), a significant rise from 2015 to 2021 (APC = 12.9708*; 95% CI: 8.0723 to 18.0914), and a sharp decline from 2021 to 2024 (APC = -33.5140*; 95% CI: -41.0596 to -25.0024), with an overall AAPC of -6.3947* (95% CI: -8.2683 to -4.4829).

The Midwest showed a steady decline from 1999 to 2015 (APC = -8.0332*; 95% CI: -8.9246 to -7.1331), a rapid rise from 2015 to 2020 (APC = 19.3439*; 95% CI: 9.5763 to 29.9821), and a sharp decline from 2020 to 2024 (APC = -22.8521*; 95% CI: -29.2674 to -15.855), with an overall AAPC of -5.7989* (95% CI: -7.7883 to -3.7667).

The South was characterized by a persistent decline from 1999 to 2014 (APC = -7.7720*; 95% CI: -8.4851 to -7.0534), a significant rise from 2014 to 2021 (APC = 10.6612*; 95% CI: 7.2412 to 14.1903), and a sharp decline from 2021 to 2024 (APC = -30.4833*; 95% CI: -37.5069 to -22.6704), with an overall AAPC of -6.1818* (95% CI: -7.5887 to -4.7535).

The West showed the steepest short-term rise of any region, with a decline from 1999 to 2016 (APC = -6.2837*; 95% CI: -7.4388 to -5.1141), followed by a sharp increase from 2016 to 2020 (APC = 45.2670*; 95% CI: 26.2242 to 67.1827), and a marked decline from 2020 to 2024 (APC = -34.6450*; 95% CI: -40.8009 to -27.8489). The overall long-term AAPC was -5.1089* (95% CI: -7.621 to -2.5285), the smallest decline of any region. Figure 4. (Supplementary Table 5)

STATES STRATIFIED TRENDS

Across the United States, notable variation in age-adjusted mortality rates was observed among states. The highest age-adjusted mortality rate was reported in Mississippi (2.999 per 100,000 population), followed by West Virginia (2.603), Alabama (2.484), District of Columbia (2.438), and Arkansas (2.191). Other states with elevated rates included North Dakota (2.182), Oklahoma (2.044), Wyoming (2.029), South Carolina (2.069), and Tennessee (2.033). In contrast, the lowest mortality rates were observed in Massachusetts (0.985), New York (1.058), Utah (1.071), Montana (1.094), and Colorado (1.179). Figure 5 (Supplementary Table 6)

Discussion

This study is the first nationwide assessment of temporal mortality trends for surgical procedures involving an anastomosis, bypass or graft (ICD-10 code Y83.2) in the United States over a 26-year period. The overall trend of mortality showed a significant decrease in the long term, albeit with a sharp rise during the late 2010s and early 2020s. A similar trend was seen in sex, race, urbanization status and

census region, but there remained significant demographic and geographic variations. This study indicates that substantial progress has been made with respect to perioperative safety and postoperative care over the years and identifies populations that are disproportionately affected by mortality.

The decreasing age-adjusted mortality over the majority of the study period may be explained by improvements in postoperative care and surgical practice. Over the last 20 years, significant advances have been made in the pre-operative risk stratification, the anesthetic technique, pre-operative monitoring, critical care, infection prevention, vascular and gastrointestinal surgical techniques, enhanced recovery protocols and multi-disciplinary postoperative management [2, 5]. Moreover, advances in less invasive and endovascular techniques, better imaging techniques, evidence-based peri-operative guidelines, and a stronger institutional focus on quality improvement initiatives may have collectively contributed in reducing deaths related to anastomosis, bypass, and graft creation [3, 5, 19].

While the overall trend was favourable, there was a notable rise in mortality from around 2015 to 2021, followed by a more significant drop in mortality. This increase coincided with the COVID-19 pandemic, which caused an enormous shift in the delivery of surgical services across the United States [20]. Studies demonstrate that concurrent COVID-19 infection markedly increased postoperative mortality with an Odds Ratio (OR) of 7.9 [20]. Some studies document a 91% reduction in elective surgical volume in the United States during the first COVID-19 surge, illustrating the major disruption to surgical care delivery [21]. The COVIDSurg Collaborative estimated that about 28.4 million elective operations would be cancelled or postponed over the 12 weeks of peak disruption due to COVID-19, representing a total cancellation rate of 72.3%, of which over 81% of operations for benign conditions would be postponed. In addition, if surgical systems were to boost their operating capacity by 20% after the pandemic, it was estimated that a median of 45 weeks would be needed to clear up the surgical work backlog. All of these unprecedented disruptions may have led to a delay in treatment, more advanced disease at presentation and a higher proportion of patients undergoing urgent or more complicated surgical interventions, adding to the initial period of increased mortality [22]. The decline after 2021 could be due to recovery of surgical services, enhanced peri-operative care in the post-pandemic period and return of normal healthcare services.

Sex-specific analyses showed that males had consistently higher mortality rates than females over the study period. This is in line with the general surgical literature, which shows that women generally experience better prognosis after surgery. In a large cohort of over 552,000 non-cardiac surgery patients, male sex was an independent predictor of all-cause mortality at 30 days, 6 months, and 1 year after surgery. Males also had significantly higher rates of hospital readmission across all time points compared to females. Notably, the adverse effect of male sex on postoperative outcomes was more pronounced in patients under 65 years of age, diminishing with increasing age [7]. The difference may be attributed to various factors, such as the increased incidence of cardiovascular disease, smoking, diabetes and chronic kidney disease in male surgical patients [7, 25]. Men are also often subjected to more complex vascular/cardiothoracic surgery, which is often performed with bypasses or grafts, and

has a higher degree of peri-operative risk [23]. However, both male and female had significant improvements at the long-term follow-up suggesting that progress in peri-operative care has had a positive impact on all surgical patients, irrespective of their sex.

Racial disparities persisted throughout the study period. The absolute mortality rates for white individuals were highest, while the long-term downward trend in mortality was relatively modest for Black individuals. The results are probably due to variations in the underlying distribution of surgical procedures and age structure, disease burden, access to healthcare, socioeconomic factors, and referral patterns, rather than just race alone [8]. Absolute rates of mortality may be higher for whites because they have a higher proportion of older patients [26]. The more modest improvement among Black individuals, on the other hand, may be due to ongoing inequities in access to healthcare, delayed presentation, higher burdens of comorbidities, structural barriers to high-quality surgical care, and varied follow-up after surgery [8]. These persistent gaps highlight the need to tackle social determinants of health, in addition to better surgical care.

Our analyses showed that patients living in rural areas had higher mortality rates than those in metropolitan areas. Access to specialized surgical centers is limited, distances to travel are longer, emergency services are delayed, high-volume surgeons are less available, workforce shortage, and there are fewer facilities to provide postoperative rehabilitation in rural areas. These structural obstacles can have a negative impact on the perioperative care and on the long-term results of more complex surgical procedures including bypass, graft formation and anastomosis [27, 11]. While mortality rates in both urban and rural areas have fallen significantly, the disparity between them indicates that the quality of surgical care received has not been equitably across geographic areas.

Significant regional variations were also observed. The decline in deaths was significant in each census region, but varied in size and timing. The significant increase observed in the Western United States in the late 2010s and early pandemic years could be due to the variations in health care delivery, COVID-19 burden, surgical case mix, referral patterns, or reporting in the region. Similarly, the consistently greater death rates seen in some Southern states (Mississippi, Alabama, Arkansas, and neighboring states) likely reflects multiple contributing factors. The prevalence of these risk factors for cardiovascular disease, diabetes, obesity, tobacco use, and socioeconomic disadvantage are higher in these states and contribute to a higher peri-operative risk [24]. Several Northeastern states, however, showed relatively low mortality, perhaps due to increased availability of tertiary referral centers, increased surgical volume, and access to specialized perioperative care [6]. These findings suggest valuable regional opportunities for targeted quality improvement activities and funding.

The majority of the mortality cases were inpatients, hospitalized for surgery, highlighting that the majority of deaths for surgical procedures assigned to Y83.2 are in the acute phase of the surgical postoperative period. These findings underscore the importance of the need to recognize postoperative deterioration early, implement standardized pathways for the management of complications, have a fast response system, multidisciplinary critical care and full monitoring in the hospital post complex surgery.

In general, our results suggest that the mortality of surgical procedures that include anastomosis, bypass or graft has significantly decreased during the last 20 years, corresponding to important improvements of surgical safety and peri-operative treatment. Yet, the temporary improvement in the COVID-19 era and the ongoing problem of inequitable access to quality surgical care, along with the geographical and demographic inequalities, indicate that further action is needed to ensure that everyone can access the same high-quality surgical care, that the health system is resilient during future health crises, and that perioperative management is optimized in populations that are at higher risk.

Limitations and Strengths

There are some limitations of this study. First, it is based on data from death certificates present on the CDC WONDER Multiple Cause of Death database, which may have potential errors due to death certification, coding, and misclassification of the underlying or contributing cause of death. Second, external causes indicated by the surgical operation given as a diagnosis in ICD-10 code Y83.2 include all surgical operations involving anastomosis or bypass or graft, but do not take into account the exact surgical operation or its underlying disease or the mechanism of death or the nature of the postoperative complication. Therefore, there was no possibility of procedure-specific or complication-specific analysis. Third, the database does not contain detailed clinical information about the patients, such as comorbidities, operative urgency, indication for surgery, surgical technique, perioperative complications, hospital characteristics, surgeon experience, postoperative interventions or timing between surgery and death, which restricts the ability to adjust for potential confounding factors. Fourth, because it is an observational ecological study, a causal link cannot be assumed between the time trends and any improvements in the surgical care and healthcare policy. Fifth, mortality patterns observed may have been affected by changes in coding practices, reporting completeness and healthcare utilization over time, especially during the COVID-19 pandemic. Lastly, mortality data do not give any information about the morbidity after surgery or long-term functional outcomes of those who survived.

This study has several strengths. It leverages a broad, nationally representative dataset of deaths over a 26-year period, allowing for the robust assessment of long-term temporal trends and differences by sex, race, geographic region, urbanization level and individual states. Age-adjusted mortality rates and Joinpoint regression offer powerful tools to evaluate overall mortality trends over time and to detect changes in mortality rates that occurred at a specific period of time.

Conclusion

Mortality associated with surgical operations involving anastomosis, bypass, or graft (ICD-10 code Y83.2) declined significantly in the United States between 1999 and 2024, reflecting substantial progress in perioperative management and surgical care. Nevertheless, a temporary increase in mortality during the late 2010s and early COVID-19 period interrupted this favorable trajectory, and important disparities persisted across sex, race, urbanization status, census regions, and states.

The results highlight the need for continued efforts to enhance the quality of surgical care, to improve perioperative care pathways, and to reduce inequities in access to specialized surgical care, especially in rural areas and areas with high surgical burden. Additional research is required that includes data at the patient level, data specific to the procedure, and data specific to the hospital to more clearly define mechanisms of these differences and to inform targeted interventions to further reduce postoperative mortality. (Figure 6)

Note: This paper complies with TITAN-2025 guidelines and checklist [28].

Declarations

Ethical approval

Ethical approval and consent to participate was not required in this editorial.

Conflicts of interest disclosure

The authors have no competing interests to declare.

Supplementary Table 1

Place of death due to complications after graft and bypass surgeries.

Supplementary Table 2

Sex-stratified and overall mortality due to complications after graft and bypass surgeries.

Supplementary Table 3

Race-stratified mortality due to complications after graft and bypass surgeries.

Supplementary Table 4

Urban and rural mortality due to complications after graft and bypass surgeries.

Supplementary Table 5

Census Region-specific mortality due to complications after graft and bypass surgeries.

Supplementary Table 6

State-specific mortality due to complications after graft and bypass surgeries.

Author Contribution

Conceptualization of ideas: SHS,NK, SMN; Manuscript preparations: SHS, SMN, UA, HGM, MA, AH, NK; Writing of initial draft: SHS, SMN, UA;Review and Editing: SHS, SMN, UA, HGM, MA, AH, NK;Final draft: All authors approved the final manuscript.

Data availability statement.

Data is provided within the manuscript and the supplementary information files

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Figures

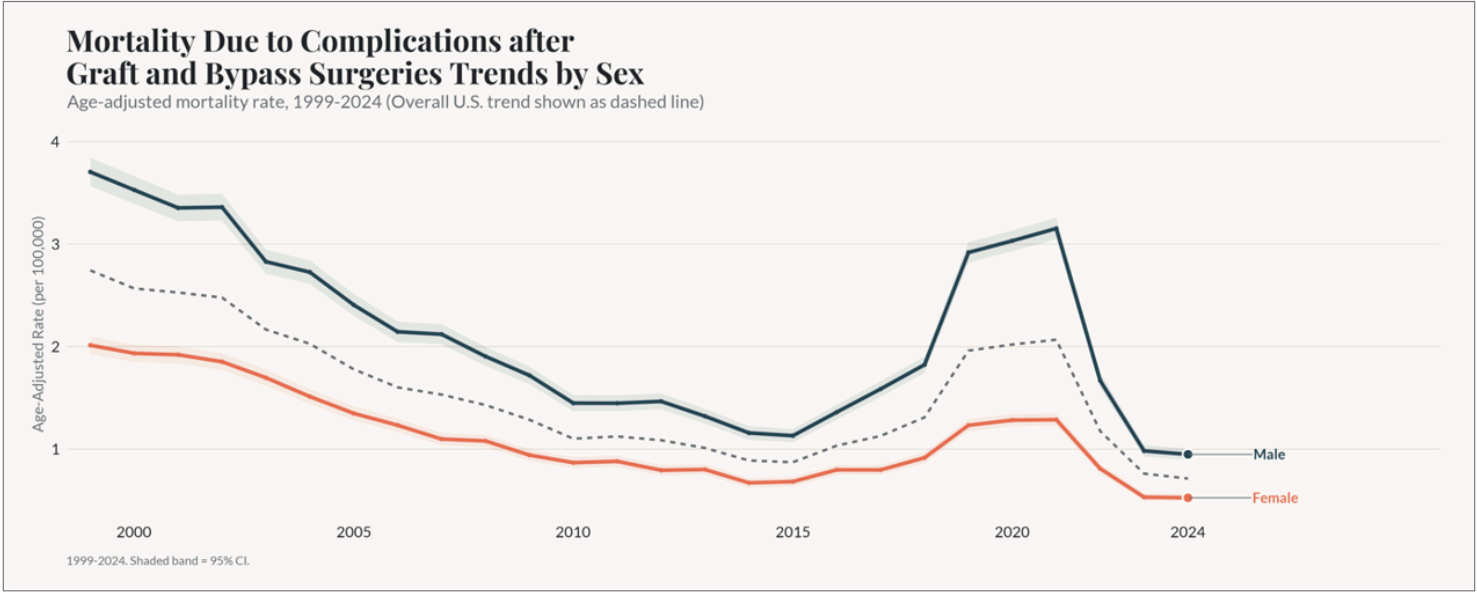


Figure 1

Age-adjusted mortality rates and Joinpoint trends overall and by sex, United States, 1999–2024. Points represent observed annual AAMRs and lines represent fitted Joinpoint segments. An asterisk indicates that the APC differed significantly from zero at $P<0.05$.

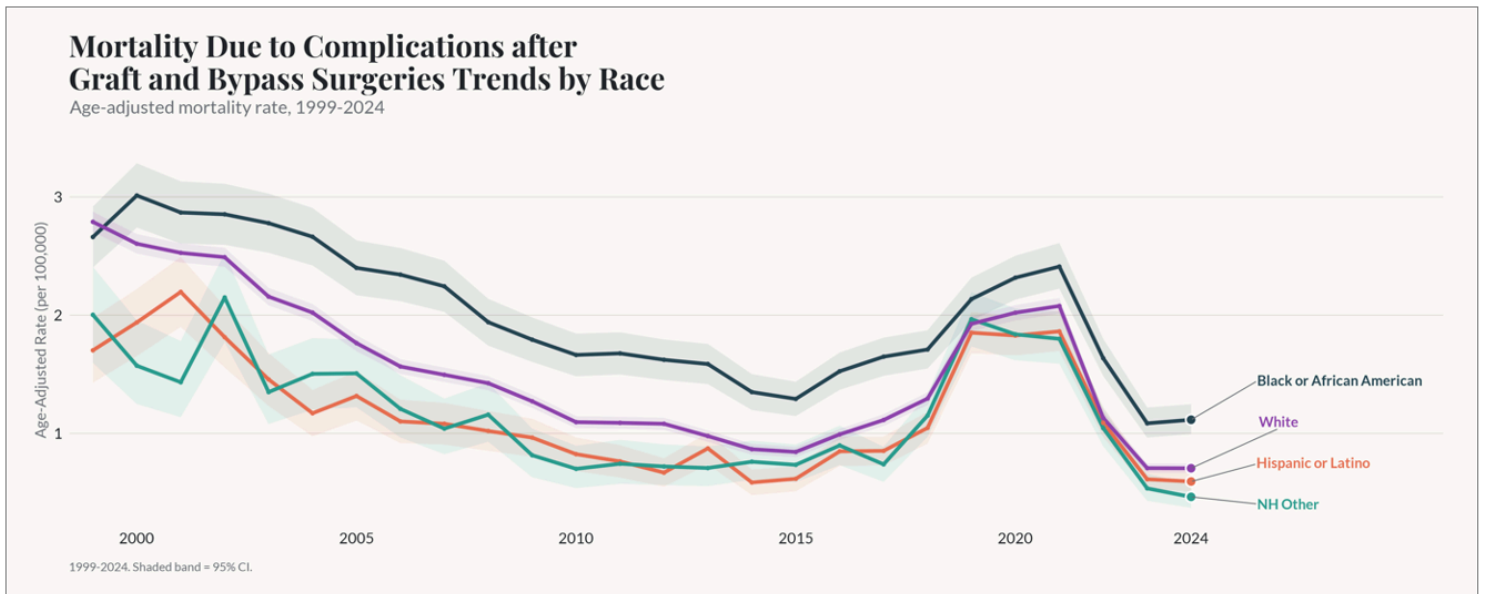


Figure 2

Age-adjusted mortality rates and Joinpoint trends by race and ethnicity, United States, 1999–2024. NH indicates non-Hispanic. Points represent observed annual AAMRs and lines represent fitted Joinpoint segments. An asterisk indicates statistical significance at $P < 0.05$.

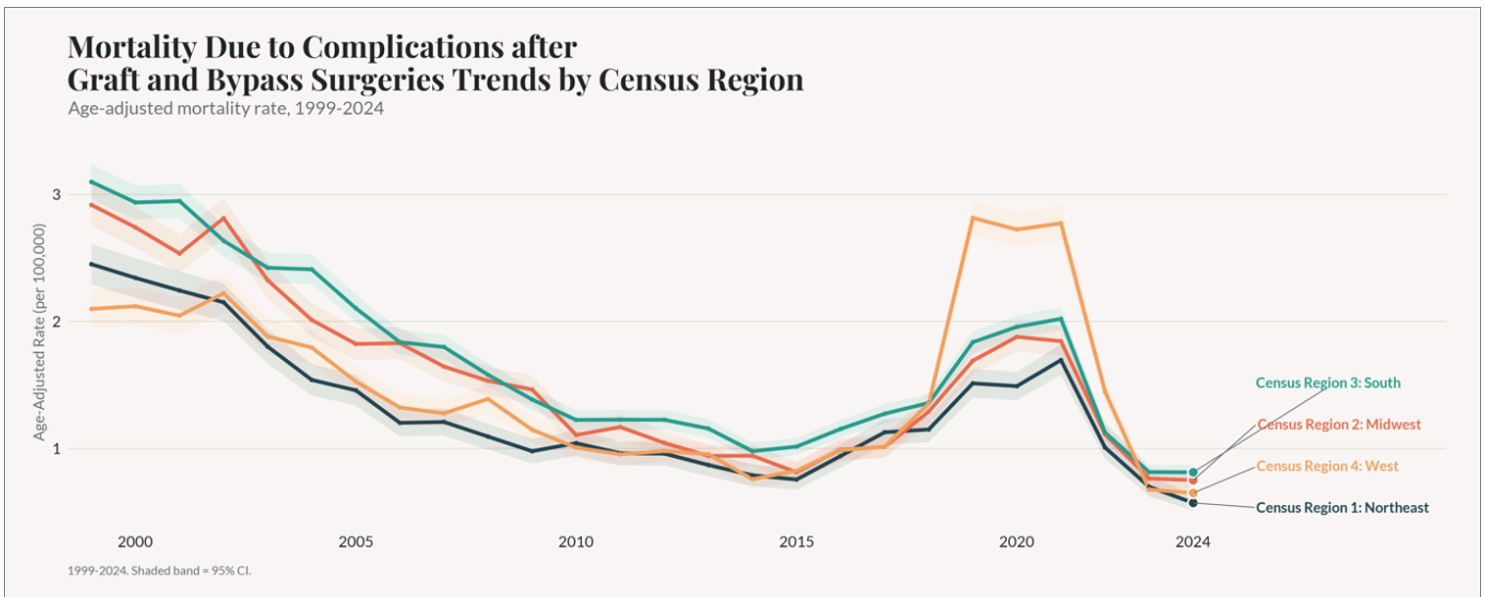


Figure 3

Age-adjusted mortality rates and Joinpoint trends by urbanization status, United States, 1999–2020. Points represent observed annual AAMRs and lines represent fitted Joinpoint segments. An asterisk indicates statistical significance at $P < 0.05$.

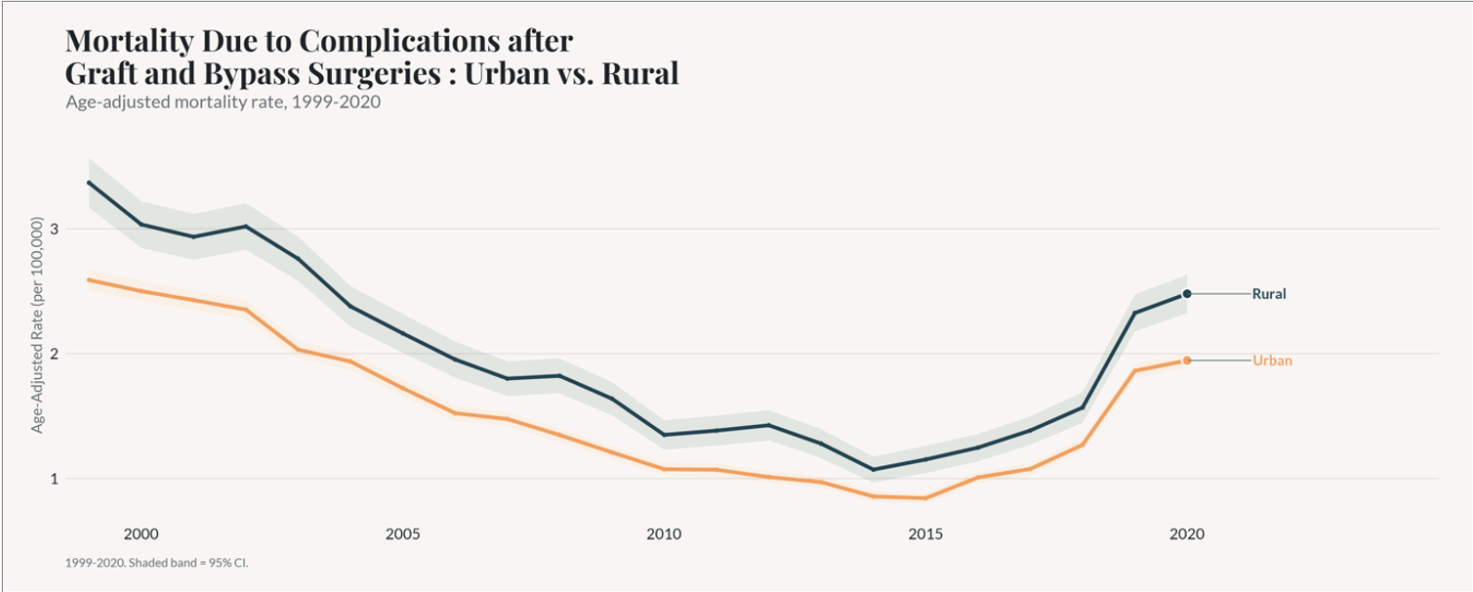


Figure 4

Age-adjusted mortality rates and Joinpoint trends by U.S. Census region, 1999–2024. Points represent observed annual AAMRs and lines represent fitted Joinpoint segments. An asterisk indicates statistical significance at $P < 0.05$.

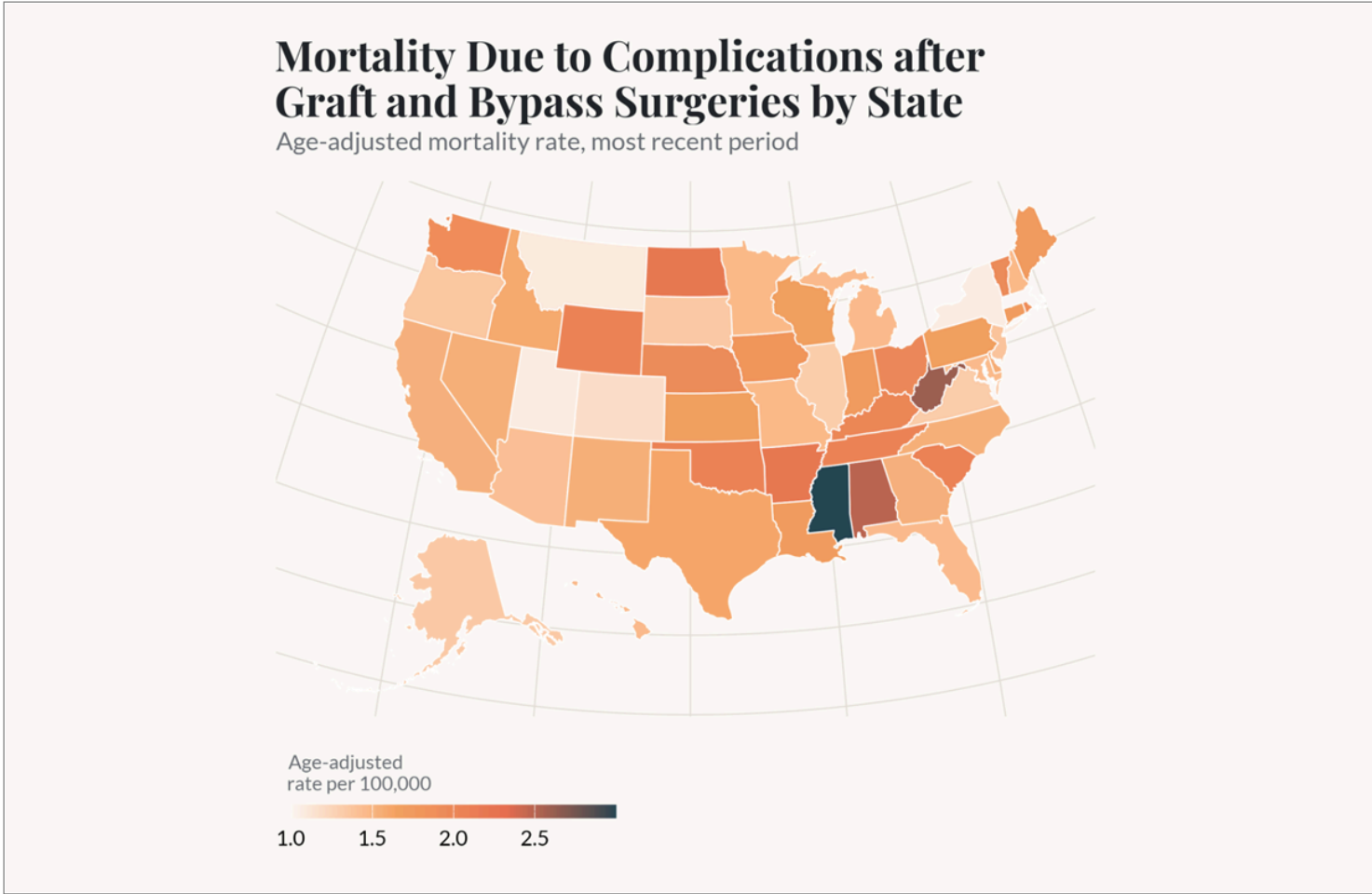


Figure 5

Pooled state-level age-adjusted mortality rates with 95% confidence intervals, United States, 1999–2024. States and the District of Columbia are ranked from the lowest to the highest AAMR

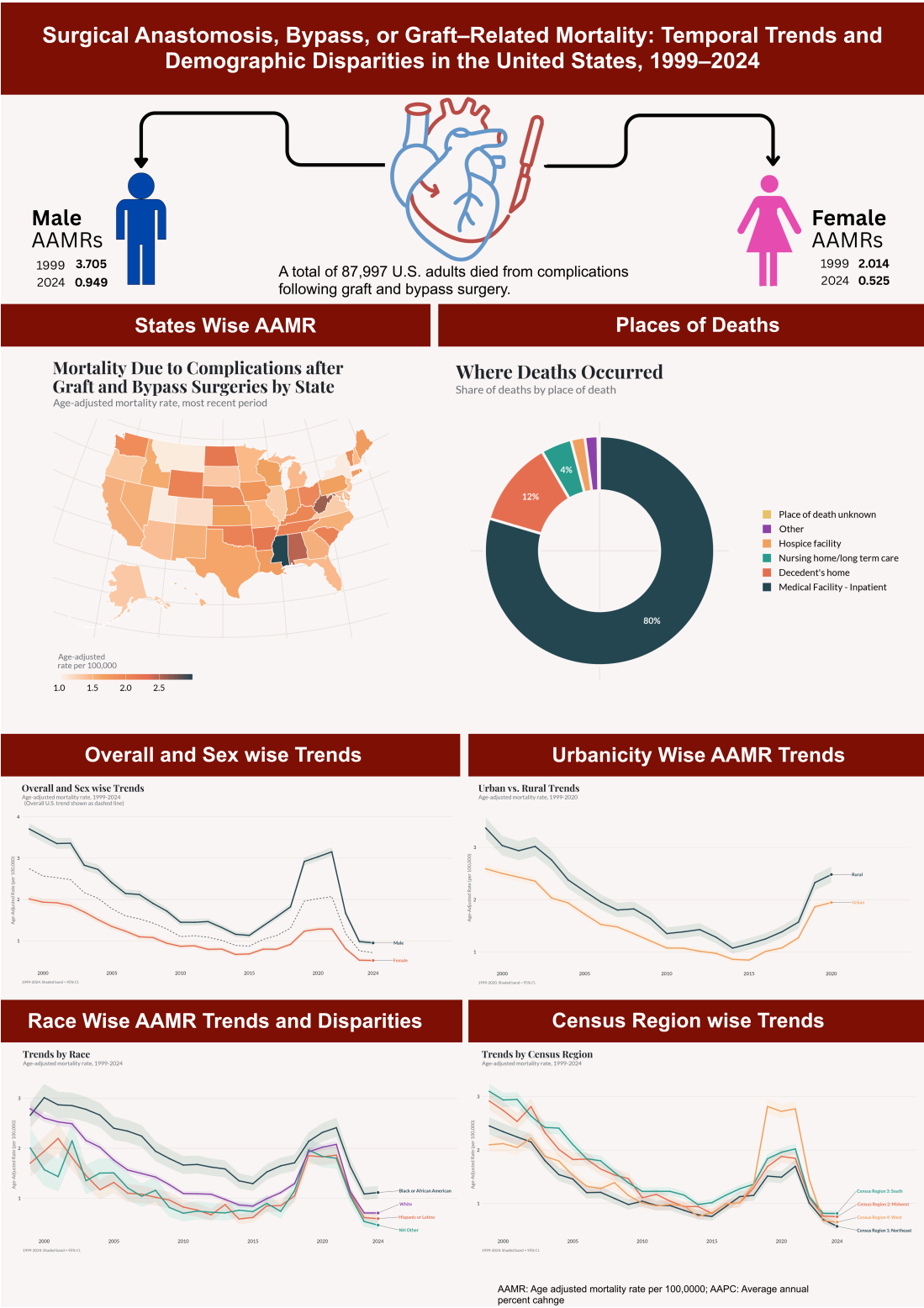


Figure 6

Supplementary Files

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