GLOBAL VOICES - SCIENCE

Cardiac implantable electronic device deaths: A cross-sectional analysis of rural and urban disparities 1999–2020

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There has been an increase in implantation of cardiac implantable electronic devices (CIEDs) in recent years. The incidence of adverse events associated with these procedures is expected to increase. The implications of these developments are particularly concerning in rural areas of the United States, where public health challenges are frequent and access to specialized medical providers is limited.[1] Our study aimed to evaluate rural and urban disparities related to CIED mortality in the United States from 1999 to 2020.

We extracted mortality data from the Centers for Disease Control and Prevention WONDER (Wide-ranging Online Data for Epidemiologic Research) database spanning the years 1999 to 2020.[2] We identified all decedents associated with the International Classification of Diseases–Tenth Revision code of T82.1 (mechanical complication of cardiac electronic device) within the multiple cause-of-death records, which covers mechanical complications from CIED implantations such as obstruction, breakdown, leakage, malposition, displacement, protrusion, or perforation. These deaths were classified into rural or urban categories based on the 2013 National Center for Health Statistics criteria. We collected demographic details from all included deaths, including age, sex, race, and U.S. census region, from the death certificates. To adjust death counts for age, we utilized the direct method with the year 2000 U.S. standard population. This allowed us to calculate and compare age-adjusted mortality rates (AAMRs) per 1,000,000 population between urban and rural areas, both cumulatively and across demographic groups. Rate ratios were calculated by dividing AAMR of rural deaths by that of urban deaths. Using the delta method, the 95% confidence intervals (CIs) were initially estimated on the natural log scale of the rate ratios and were then established by exponentiating the lower and upper bounds of the CI. Institutional Review Board approval was not required given the use of government-issued publicly available data. Our study adhered to the STROBE (Strengthening the Reporting of Observational studies in Epidemiology) guidelines.

There were a total of 419 deaths in rural regions and 1129 deaths in urban regions. The AAMR was higher among rural regions (AAMR 0.31, 95% CI 0.28–0.34) compared with urban regions (AAMR 0.18, 95% CI 0.17–0.20) (Table 1). Among individuals $<$ 65 years of age, mortality was similar among rural (AAMR 0.05, 95% CI 0.03–0.06) and urban (AAMR 0.03, 95% CI 0.02–0.03) regions. Conversely, mortality was higher among adults $\geq$65 years of age in rural regions (AAMR 2.16, 95% CI 1.93–2.38) compared with urban regions (AAMR 1.28, 95% CI 1.20–0.37).

Within rural U.S. regions, both male (AAMR 0.40, 95% CI 0.34–0.46) and female (AAMR 0.26, 95% CI 0.23–0.30) decedents had a higher AAMR compared with their male (AAMR 0.22, 95% CI 0.20–0.24) and female (AAMR 0.16, 95% CI 0.15–0.17) decedent counterparts in urban regions. Black populations were disproportionately impacted by higher mortality in rural regions (AAMR 0.28, 95% CI 0.17–0.42) compared with urban regions (AAMR 0.21, 95% CI 0.17–0.24). Similarly, White populations were impacted by higher mortality in rural regions (AAMR 0.31, 95% CI 0.28–0.35) compared with urban regions (AAMR 0.17, 95% CI 0.16–0.19).

Within Northeastern U.S. regions, mortality was higher in rural areas (AAMR 0.34, 95% CI 0.25–0.46) compared with urban areas (AAMR 0.18, 95% CI 0.15–0.20).

KEYWORDS Cardiac device; Implantable; Electronic; Disparities; Urbanization (Heart Rhythm O2 2024;5:307–309)

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KEY FINDINGS

- Rural populations have higher cardiac implantable electronic device–related mortality when compared with urban populations.
- The abundance of tertiary care centers, cardiac specialists, and access to advanced equipment in urban areas are likely major factors contributing to this mortality disparity.
- Further investigation into patient-level socioeconomic factors is warranted to understand its impact on this rural-urban cardiac implantable electronic device death disparity.

Similarly, mortality in rural regions was higher along the other U.S. census regions (Midwest AAMR 0.29, 95% CI 0.24–0.34; South AAMR 0.30, 95% CI 0.25–0.35; and West AAMR 0.37, 95% CI 0.29–0.48) compared with urban regions in the same U.S. census regions (Midwest AAMR 0.20, 95% CI 0.17–0.22; South AAMR 0.19, 95% CI 0.17–0.21; and West AAMR 0.17, 95% CI 0.14–0.19).

Our analysis provides insights into the rural and urban mortality disparities related to CIED mechanical complications within the United States. Rural regions experienced a disproportionately higher mortality rate compared with their urban counterparts, consistently seen across various demographic subpopulations. These findings emphasize that mortality disparities in rural areas remains a major concern, despite significant public health and policy efforts to address inequities.

This rural-urban outcome disparity is likely to be multifactorial, including CIED operator characteristics and healthcare access barriers. The shortage of cardiac specialists in rural areas has led to an increased reliance on general cardiologists to perform CIED procedures, increasing risk of procedural complications and higher mortality.[3] Higher prevalence of tertiary hospitals with advanced facility and equipment also contributes to lower procedure-related complications and lower mortality in urban regions compared with resource-limited regions.[1] Greater annual procedure volume in these tertiary hospitals is also associated with less adverse outcome after CIED procedures.[4] Furthermore, the disparity in access to healthcare, poor health literacy, and poverty in rural areas may lead to missed postprocedure follow-up or delayed management of postprocedure complications.[5] Finally, our analysis identified that Black populations showed no significant variance in mortality rates between rural and urban settings. This finding suggests a possible uniformity in access to healthcare resources for Black populations, irrespective of their urbanization status.[6]

There are limitations to our study. This includes misclassification errors from use of International Classification of Diseases–Tenth Revision codes, undifferentiated reporting between CIED types, and the absence of individual-level data, which constrained our ability to account for residual confounding. Additionally, the potential for ecological fallacy must be acknowledged, as it constrains the extent to which these findings can be applied to the patient level. Finally, our analysis did not account for the time elapsed from the procedure to the occurrence of death. Despite these limitations, our analysis is strengthened by utilization of the Centers for Disease Control and Prevention WONDER database, a nationally representative sample.

Table 1 CIED-related death

	Rural			Urban			
Population	Death count	Population size	AAMR (95% CI)	Death count	Population size	AAMR (95% CI)	RR (95% CI)
All	419	1,006,871,652	0.31 (0.28–0.34)	1129	5,739,475,649	0.18 (0.17–0.20)	1.72 (1.54–1.93)
Age							
<65 y	55	838,893,105	0.05 (0.03–0.06)	172	4,978,979,001	0.03 (0.02–0.03)	1.67 (1.23–2.26)
≥65 y	364	167,978,547	2.16 (1.93–2.38)	957	760,496,648	1.28 (1.20–1.37)	1.69 (1.50–1.90)
Sex							
Male	210	502,292,400	0.40 (0.34–0.46)	534	2,815,055,490	0.22 (0.20–0.24)	1.82 (1.55–2.13)
Female	209	504,579,252	0.26 (0.23–0.30)	595	2,924,420,159	0.16 (0.15–0.17)	1.63 (1.39–1.90)
Race							
Black	21	88,267,994	0.28 (0.17–0.42)	137	830,766,851	0.21 (0.17–0.24)	1.33 (0.84–2.11)
White	393	881,053,153	0.31 (0.28–0.35)	970	4,485,984,657	0.17 (0.16–0.19)	1.82 (1.62–2.05)
U.S. Census region							
Northeast	47	101,993,585	0.34 (0.25–0.46)	251	1,111,001,337	0.18 (0.15–0.20)	1.89 (1.38–2.58)
Midwest	145	333,404,572	0.29 (0.24–0.34)	248	1,132,716,642	0.20 (0.17–0.22)	1.45 (1.18–1.78)
South	163	429,500,294	0.30 (0.25–0.35)	395	2,068,317,787	0.19 (0.17–0.21)	1.58 (1.32–1.90)
West	64	141,973,201	0.37 (0.29–0.48)	235	1,427,439,883	0.17 (0.14–0.19)	2.18 (1.65–2.87)

The CIED-related death counts, corresponding population size, and AAMRs in the cumulative U.S. population and among demographic groups. RRs show rates of rural AAMRs compared with urban AAMRs.

AAMR = age-adjusted mortality rate; CIED = cardiac implantable electronic device; CI = confidence interval; RR = rate ratio.

Our results revealed CIED-related mortality disparities among the rural regions in the United States. These findings warrant further investigation into individual-level socioeconomic factors that contribute to this healthcare inequity.

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