Iowa First Responder AED Initiative 2021-2023

January 17, 2025

Nicolas Foss, Ed.D., MS
Epidemiologist

Margot McComas, BSN, RN
Bureau Chief

IOWA | Health and Human Services

Acknowledgments

Data Citations:

State of Iowa Department of Health and Human Services. Bureau of Emergency Medical and Trauma Services. *2021-2-23 Iowa Law Enforcement AED Project Report.* Des Moines: Iowa Dept. of Public Health, 2024. Web. https://hhs.iowa.gov/public-health/emergency-medical-services-trauma/trauma-data-registry. Access date – day, month, year.

Gov. Kim Reynolds

HHS Director Kelly Garcia

Report Contact Information:

Nicolas Foss, Bureaus of Emergency Medical and Trauma Services and Health Statistics nicolas.foss@hhs.iowa.gov

515-985-9627

Neil Wellner, Bureau of Emergency Medical and Trauma Services neil.wellner@hhs.iowa.gov

515-336-9334

Margot McComas, Bureau of Emergency Medical and Trauma Services margot.mccomas@hhs.iowa.gov

515-350-8671

Ken Sharp, Division of Public Health kenneth.sharp@hhs.iowa.gov

515-321-6749

The Bureau of Emergency Medical and Trauma Services would like to acknowledge the Helmsley Charitable Trust for its generous funding that made this project possible. Special thanks to Dr. James Torner (University of Iowa) for his technical assistance.

Table of Contents

Tables and Figures

List of Figures

List of Tables

List of Acronyms

Abbreviation	Name
AED	Automated external Defibrillator
BEMTS	Bureau of Emergency Medical and Trauma Services
CPR	Cardiopulmonary Resuscitation
CDC	Centers for Disease Control and Prevention
CVD	Cardiovascular Disease
ED	Emergency Department
EMS	Emergency Medical Services
FR	First Responders
IDNR	Iowa Department of Natural Resources
IDPS	Iowa Department of Public Safety
Iowa HHS	Iowa Department of Health and Human Services
LEO	Law Enforcement Officer
NH	Non-Hispanic
OHCA	Out-of-Hospital Cardiac Arrest
PD	Police Department
ROSC	Return of Spontaneous Circulation
SO	Sheriff's Office
STEMI	Segment Elevation Myocardial Infarction

Report Guidance

While many consumers of health statistics may be aware of the information contained within this report, others may not fully understand the limitations of the data contained in this report, and how to interpret abstract representations of data such as descriptive and inferential statistics. This report includes a section that serves to provide definitions and important details about the nature and methods used to calculate key metrics referenced within the report.

Please navigate to Technical Notes to review key definitions, disclosures about the data, and formulas that can help the reader make the most out of the analytical products in this report.

Executive Summary

Project Overview

The 2021-2023 Iowa First Responder AED (FRAED) Initiative Report is the outcome of an analytical project conducted by the Bureau of Emergency Medical and Trauma Services (BEMTS). This report evaluates data collected from law enforcement records regarding the deployment of automated external defibrillators (AEDs) distributed through the corresponding grant project. Additionally, it incorporates data from Iowa's ImageTrend Elite registry, which emergency medical personnel use to document their service runs. The report aims to provide valuable insights into Iowa’s experience with cardiac arrest events, the effectiveness of AED use by law enforcement officers (LEOs), and to support data-driven decision-making for improving health outcomes in out-of-hospital cardiac arrest situations. Ultimately, this report summarizes Iowa Department of Health and Human Services’ (Iowa HHS) efforts aiming to reduce morbidity and mortality via a law enforcement AED project.

In 2020, Iowa Health and Human Services received a grant of $10,116,557.00 from the Leona M. and Harry S. Helmsley Charitable Trust for the Iowa First Responder AED Initiative. Administered by the Bureau of Emergency Medical and Trauma Services, the primary objective of this program was to equip LEOs in Iowa with automated external defibrillators to reduce mortality related to cardiac arrest. This initiative is a critical component of the state's efforts to enhance emergency medical response and improve survival rates for individuals experiencing cardiac arrest outside of hospital settings. Law enforcement agencies dedicated themselves to the safety and security of their community and the survivability of cardiac arrest events by utilizing AED units distributed for this grant project. The data collected by BEMTS for the FRAED project provide a unique view into LEO capabilities to reduce mortality from cardiac arrest events in Iowa using AED units. This report delves into the key data points, highlighting trends and challenges faced by law enforcement officers as they respond to cardiac arrest emergency calls.

Spread and Impact of Iowa FRAED

Since its inception, the First Responder Automated External Defibrillator (FRAED) project has significantly enhanced public safety and emergency response across Iowa. Utilizing Stryker's LIFEPAK CR2 AED units, the project has seen widespread adoption and success from its start through the end of 2023. As of October 15, 2024, the project involved 196 law enforcement agencies, covering 328 cities across 89 counties. This initiative has saved 242 lives, distributed 3,904 AED units out of 4,025 available (as of October 15, 2024), and officers established 357 Stryker accounts. A map of the project's distribution illustrates its extensive reach across the state.

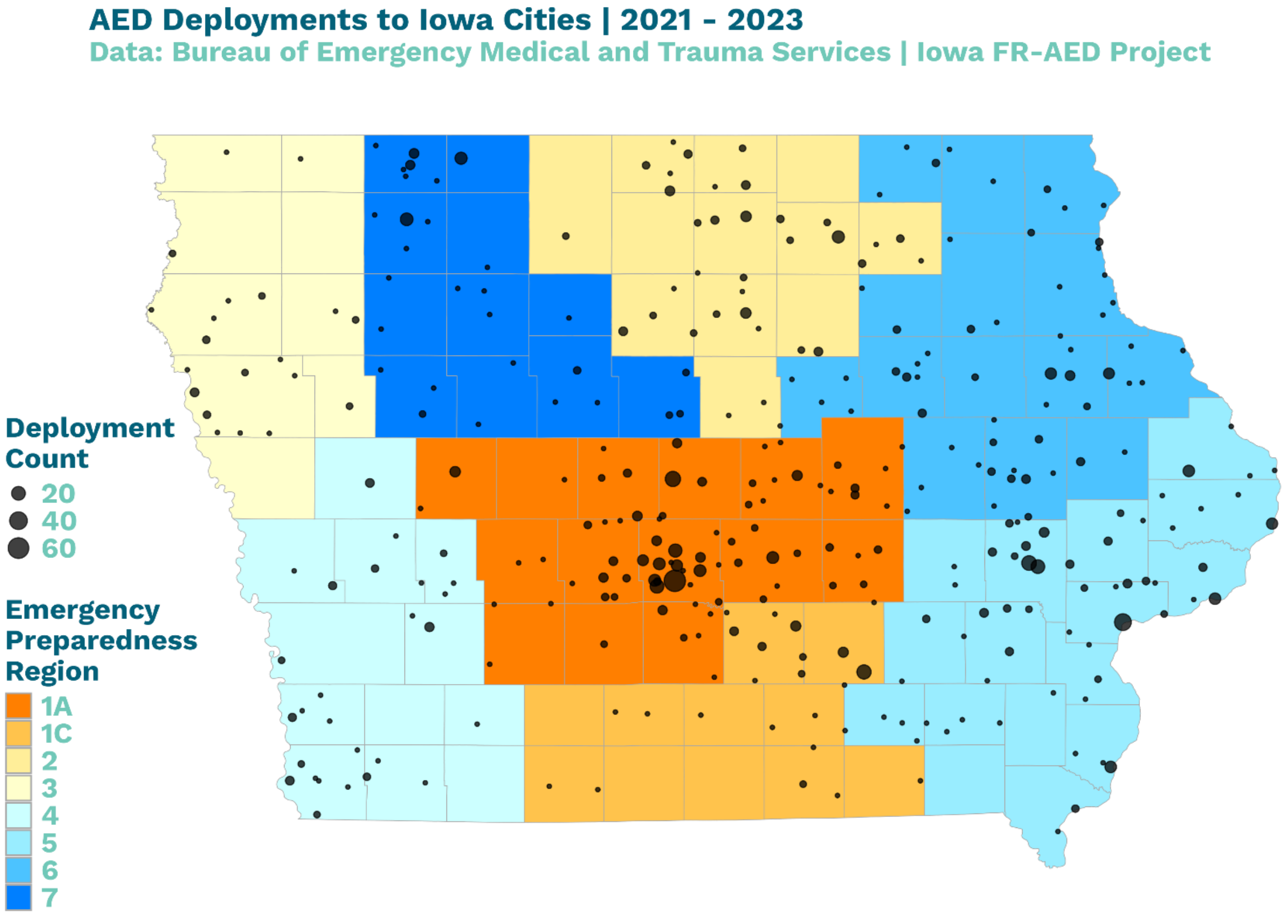


Figure 1: AED Deployments to Iowa Cities 2021-2023

Distribution Framework

The distribution of AEDs under the FRAED project follows a structured process. The first step involved contacting every law enforcement agency in Iowa and using a questionnaire to assess the number of patrol cars in each fleet. After the grant was approved, agencies were contacted to confirm their interest in participating. Once confirmed, AED units were ordered and shipped directly to the agency.

Distribution has been carefully managed to avoid overwhelming agencies with replacement pad and battery needs. The warranty for each AED begins when it is shipped from Stryker, so a staggered delivery schedule ensures agencies can benefit from the full life of the warranty. Additionally, replacement pads are provided for units used in an emergency, not for those reaching expiration.

Data Collection

Data collection is a key aspect of the FRAED project. When an AED is deployed, the BEMTS staff member is notified via email by an automated system that provides the date and time the AED was used. This triggers a series of steps to help the agency restore the AED to service, including replacing pads. BEMTS then sends the agency a survey to collect data for the BEMTS AED database.

To ensure completeness, all times are pulled from the state EMS registry. If a law enforcement agency is delayed in returning the survey, efforts are made to use the EMS registry is used to gather the necessary information about the event.

Future Goals for Maintenance

Looking ahead, the grant for the FRAED project is set to expire in July 2025. However, ongoing efforts to secure funding will allow the project to continue beyond this date. The project team is working with the Iowa Department of Health and Human Services (HHS) to explore potential funding sources to support the law enforcement AED initiative long-term.

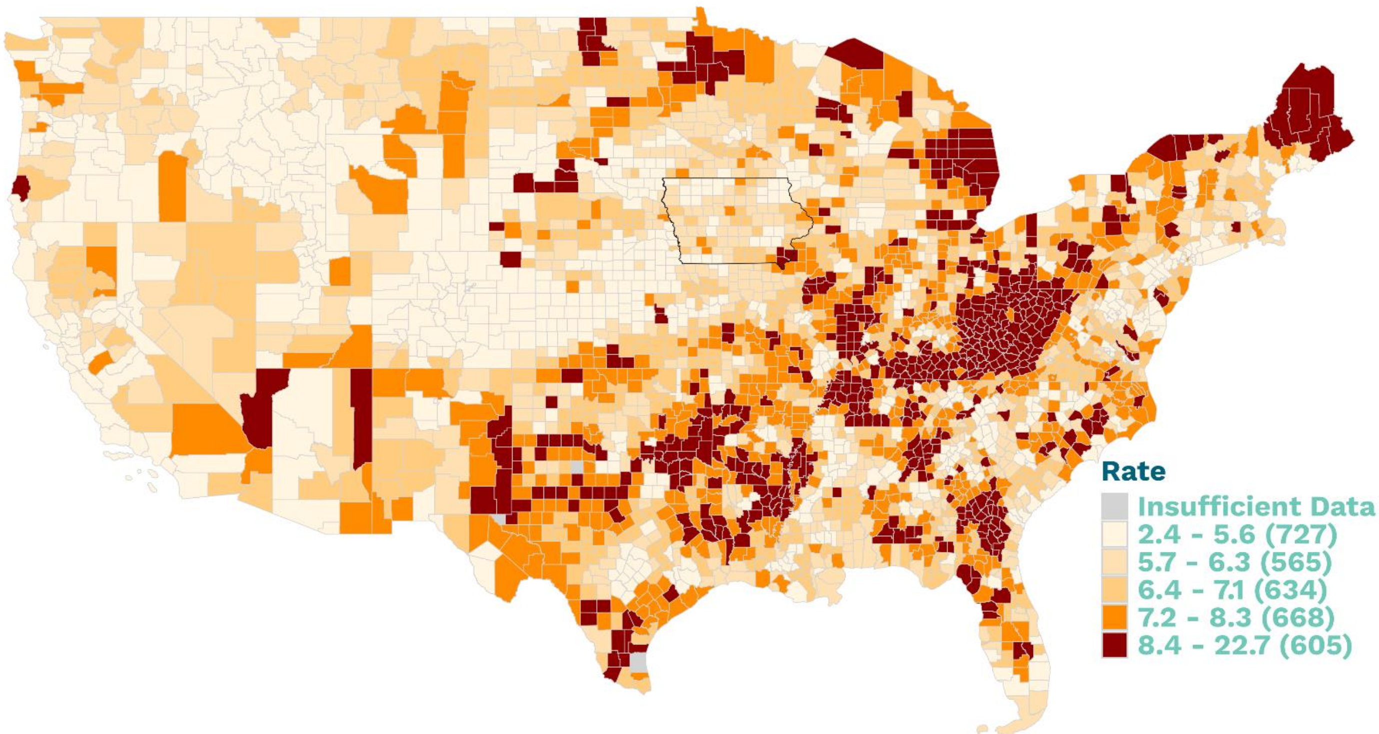
In addition to sustaining the program, there are plans to increase community awareness around the use of CPR and AEDs, providing further support to local efforts in emergency preparedness and response.

National Context for the FRAED Project

Cardiac Arrest Hospitalizations In the U.S.

Continental U.S. Heart Attack Hospitalization Rate per 1,000 Medicare Beneficiaries

All Races/Ethnicities, All Genders, Ages 65+, 2019-2021



Data: Centers for Disease Control and Prevention. Interactive Atlas of Heart Disease and Stroke. http://nccd.cdc.gov/DHDSPAtlas. Accessed on 10/15/2024.

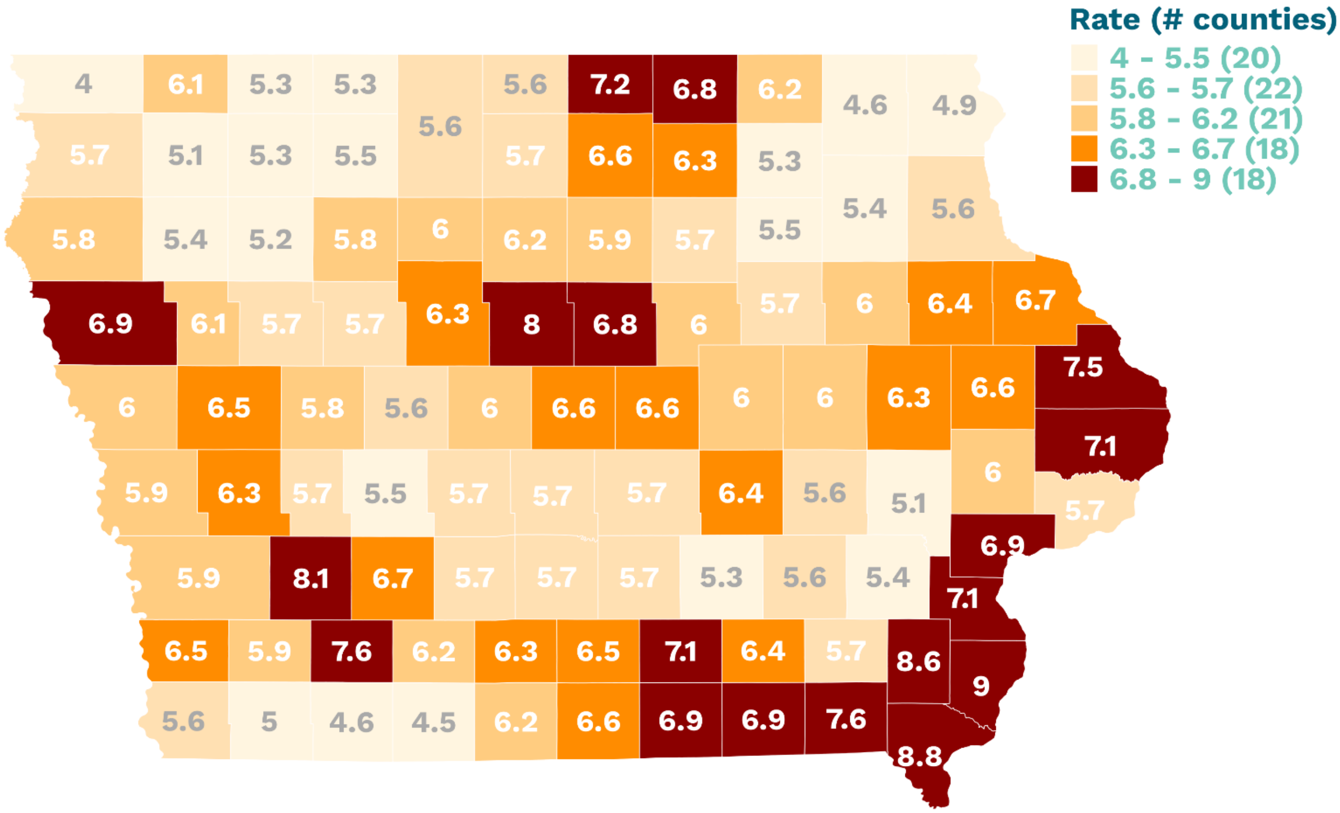
Figure 2: Heart Attack Hospitalization Rate per 1,000 Medicare Beneficiaries in the Continental U.S.

It is important to understand the context of heart health in the United States and Iowa to appropriately interpret the evaluation of the FRAED project. In the choropleth map above, the counties are colored in comparison to each other based on an age adjusted rate for all genders, races, and ethnicities for people ages 65+ provided by the CDC. The absolute values of the corresponding rates are not relative. Iowa is outlined in the Midwest for ease of comparison to other regions in the U.S. Between 2019-2021, the counties of Des Moines, Henry, and Lee were the only counties in the most severe category as compared to all other counties in the continental U.S. The estimates above by the CDC used spatial smoothing techniques as well as age adjustment for all calculated rates, making the rates comparable between jurisdictions.

Cardiac Arrest Hospitalizations in Iowa

Iowa Heart Attack Hospitalization Rate per 1,000 Medicare Beneficiaries

All Races/Ethnicities, All Genders, Ages 65+, 2019-2021



Data: Centers for Disease Control and Prevention. Interactive Atlas of Heart Disease and Stroke. http://nccd.cdc.gov/DHDSPAtlas. Accessed on 10/15/2024.

Figure 3: Heart Attack Hospitalization Rate per 1,000 Medicare Beneficiaries in Iowa

Based on a comparison of national estimates of heart attack hospitalizations, Iowa overall is close to the national average. However, the choropleth map above highlights some important trends based on rates provided by the CDC for all genders, races, ethnicities, and only for individuals ages 65+ in Iowa. Clearly, there are regions of the state that have higher concentrations of heart attack hospitalizations based on comparative estimates using spatial smoothing techniques. Overall, the furthest Southeastern section of the state contains a high concentration of counties with high rates. This section stretches as far west as Appanoose and Monroe counties, goes to Lee County, and stretches north to Muscatine County. There is a gap at Scott County, and the next two counties north part of this stretch are Clinton and Jackson counties. This map further highlights the importance of making resources available to respond to out of hospital cardiac arrest.

Importance of Law Enforcement AED Programs

Out-of-hospital cardiac arrest (OHCA) is a leading cause of morbidity and mortality worldwide, with significant implications for public health (Tsao et al., 2023). As the prevalence of cardiovascular disease (CVD) continues to rise in the United States, it is crucial to explore effective intervention strategies, such as law enforcement Automated External Defibrillator (AED) programs. These programs facilitate the integration of AEDs into law enforcement agencies, ensuring timely access to life-saving equipment and training for first responders. This report examines the epidemiology of heart disease, OHCA, and heart disease mortality rates in the U.S. and Iowa, highlighting the necessity of AED programs in law enforcement settings.

EPIDEMIOLOGY OF HEART DISEASE IN THE U.S.

Mortality

In the United States, one person dies every 33 seconds from heart disease (National Center for Health Statistics [NCHS], 2024). Heart disease is the leading cause of death across various demographic groups in the United States, resulting in approximately 702,880 deaths in 2022—equivalent to one in every five deaths (NCHS, 2024; Martin et al., 2024). Overall, the total financial burden on Americans related to heart disease is an estimated $252.2 billion from 2019 to 2020 (Martin et al., 2024). These alarming statistics highlight the critical need for effective emergency response measures, particularly the deployment of automated external defibrillators (AEDs) by law enforcement.

Groups Affected by Heart Disease

Mortality rates associated with heart disease also reveal disparities across racial and ethnic groups. Heart disease remains the leading cause of death for many groups, including African Americans, American Indians, Alaska Natives, Hispanics, and White men, with heart disease being the second leading cause of death for Pacific Islander and certain Asian women (NCHS, 2024). The percentages of deaths caused by heart disease in 2021 varied significantly by race and sex, emphasizing the widespread impact of this condition across the population (NCHS, 2024).

Race or Ethnic Group	% of Deaths (CDC, n.d.)
American Indian or Alaska Native	15.5
Asian	18.6
Black (Non-Hispanic)	22.6
Native Hawaiian or Other Pacific Islander	18.3
White (Non-Hispanic)	18.0
Hispanic	11.9
All	17.4

Table 1: CDC Heart Disease Mortality Estimates by Race

The Role of Law Enforcement AED Programs

Law enforcement AED programs are critical in addressing the gaps in emergency response to OHCA. These programs equip law enforcement agencies with AEDs, provide necessary training, and ensure that the financial burdens associated with these programs are alleviated through funding initiatives. By placing AEDs in police vehicles, first responders can quickly access life-saving equipment, thereby improving the chances of survival for individuals experiencing cardiac arrest.

Considering these statistics, integrating AEDs into law enforcement operations is not only advantageous but essential. AEDs significantly increase survival chances for individuals experiencing sudden cardiac arrest, making their availability in public spaces critical for enhancing community health outcomes. By equipping law enforcement officers with AEDs, communities can foster a more responsive emergency environment that addresses the pressing realities of heart disease in the United States.

Enhanced Response Times

Research suggests that the integration of AEDs into law enforcement operations significantly reduces response times to cardiac arrest incidents (Folke et al., 2023). Recent developments in public access defibrillation strategies, including volunteer responder programs and drone-assisted AED delivery, have significantly improved early defibrillation rates beyond the limited range of on-site AEDs. These advancements, critical for enhancing survival rates after out-of-hospital cardiac arrest (OHCA), enable faster response times in both public and private locations (Folke et al., 2023). Innovations, such as wearable devices that transmit vital signs to emergency medical services (EMS), offer promising avenues to address previously untreated, unwitnessed cardiac arrests. Despite this potential, more randomized clinical trials are necessary to confirm the survival benefits of these strategies. Policymakers must prioritize investments in infrastructure to ensure successful resuscitation efforts.

CONCLUSION

The epidemiological evidence underscores the urgency of implementing law enforcement AED programs as a vital strategy for addressing the public health crisis posed by out-of-hospital cardiac arrests. Given the high prevalence of cardiovascular disease and the associated mortality rates in the U.S. and Iowa, equipping law enforcement agencies with AEDs represents a critical intervention. By enhancing access to life-saving technology and training first responders, we can improve survival rates for individuals experiencing cardiac arrest, ultimately saving lives and strengthening community health.

Iowa FRAED Deployment Statistics

AED Deployment Details

DEPLOYMENTS

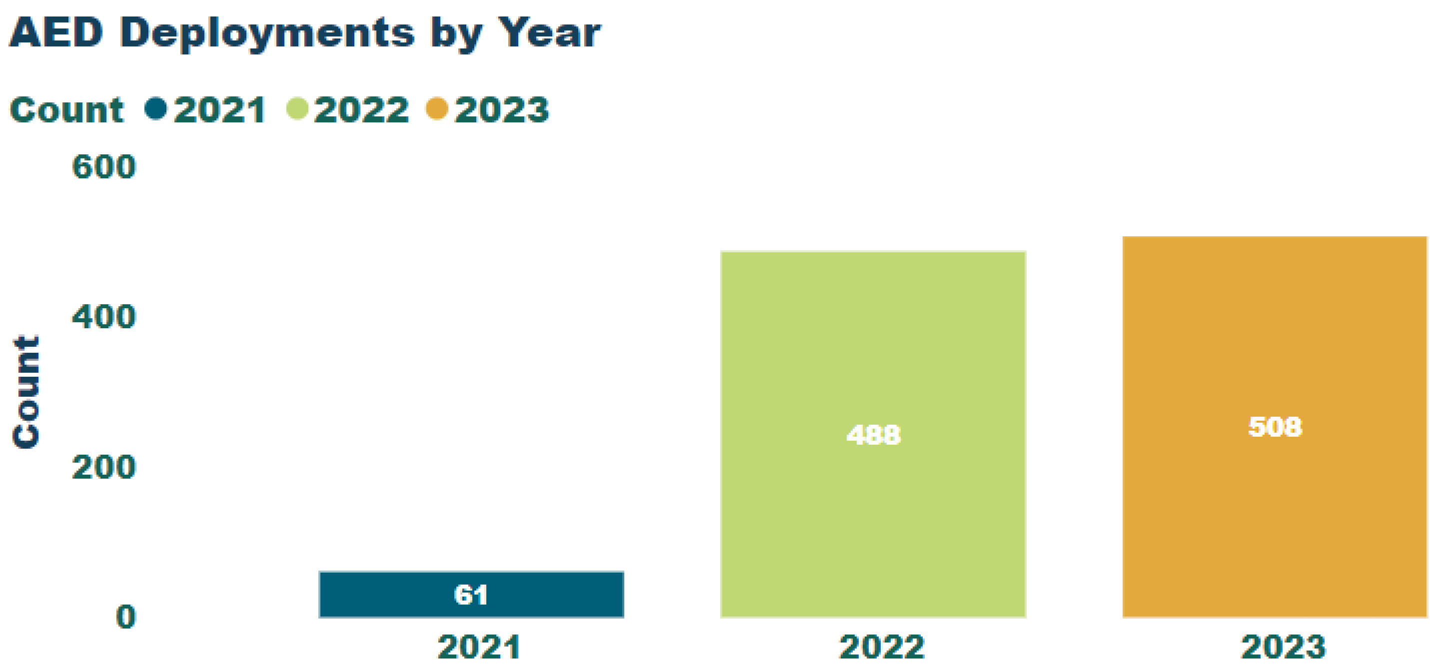


Figure 4: Count of AED Deployments by Year

Significant gains were made from the beginning of the project period in mid-2021 and through the end of the project period in December 2023. In 2021, the FRAED project was just getting off the ground which entailed getting staff in place for the effort, enrolling law enforcement agencies, and distributing the AEDs. As such, the year 2021 only reflects a few months of active AED deployments after the project started. From 2022 to 2023, the AED project gained 4.1%

CALL TYPE

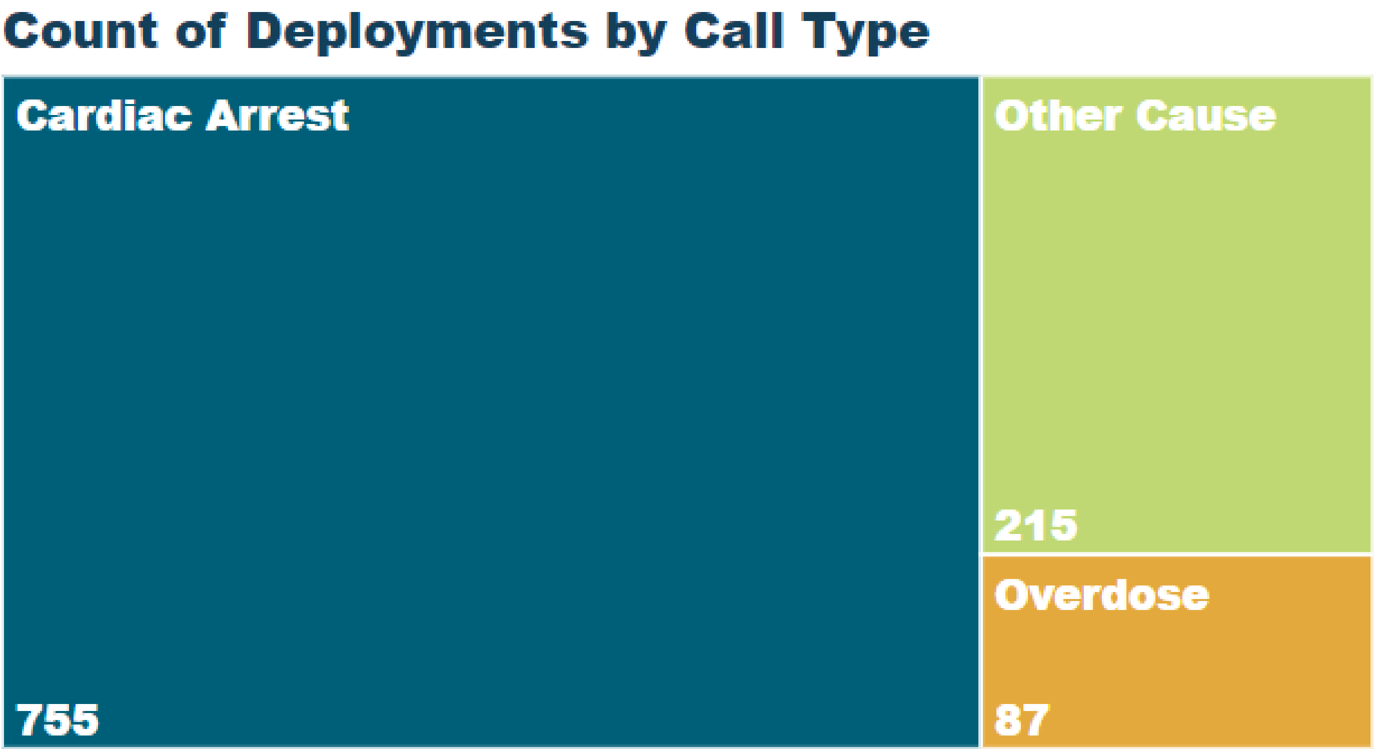


Figure 5: Deployments by Call Type

From 2021 to 2023, law enforcement agencies responded to a total of 1,057 calls related to a reported cardiac arrest event. The incidents in the database maintained by BEMTS are categorized each as a cardiac arrest call, overdose, or other cause (suicide, motor vehicle crash, fall, etc.). From mid-2021 through calendar year 2023, 755 cardiac arrest calls, 87 calls due to an overdose, and 215 calls due to other causes. Overall, these calls resulted in a survival rate of 22.9% among the 1,057 cardiac arrest responses. The call type survival rates were 12.7% for cardiac arrest calls, 34.4% for other causes, and 81.6% for overdose calls.

Among the agencies that responded, 615 were Police (58.2%), 398 were Sheriff (37.7%), 30 were Iowa Department of Public Safety (2.8%), and the rest were from Iowa Department of Nature Resources – Parks, Iowa Department of Transportation Motor Vehicle Enforcement, and Conservation. The project started with 33 law enforcement agencies participating in 2021, and grew to 137 agencies participating in 2022, and 161 participating in 2023, for a total of 196 different agencies participating in the project.

WITNESSED ARREST

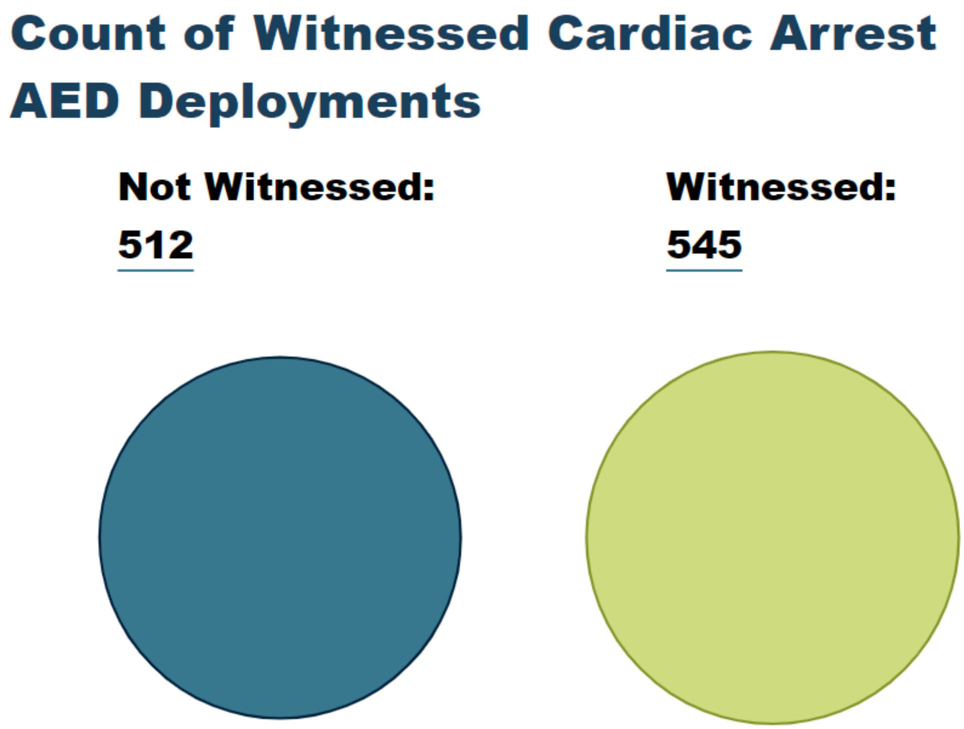


Figure 6: AED Deployments with Witnessed Arrest Data

Of the 1,057 cardiac arrests recorded, 545 (51.6%) were witnessed, while 511 (48.4%) were unwitnessed, with one record missing witnessed status data. The nearly equal distribution highlights the importance of rapid AED deployment in both witnessed and unwitnessed cases. Witnessed arrests benefit from immediate intervention, but the substantial proportion of unwitnessed cases reinforces the need for widespread AED availability, as early defibrillation remains crucial even in delayed recognition. These data emphasize the program's broad reach and its potential to improve outcomes across various arrest scenarios.

BYSTANDER CPR

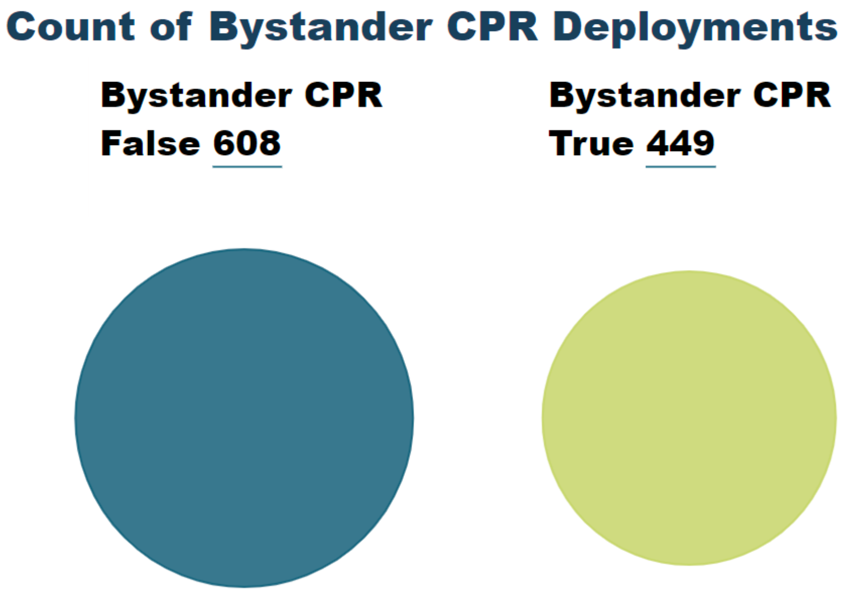


Figure 7: Deployments by Bystander CPR Data

Of the 1,057 cardiac arrests recorded, 449 cases (42.5%) involved bystander CPR, while 608 cases (57.5%) did not receive bystander CPR. These data underscore the need for continued efforts to increase public awareness and training in CPR, as immediate bystander intervention can significantly improve survival rates. The relatively lower incidence of bystander CPR highlights an opportunity for community outreach and education to further enhance the impact of the First Responder AED program in emergency cardiac care.

AED DEPLOYMENTS BY AGENCY TYPE

Figure 8: Deployments by Agency Type

Data labels for some groups are masked to protect confidentiality due to a low count. Law enforcement agencies played a critical role in AED deployments, with Police Departments (PD) leading at 58.2% of all responses (615 incidents). Sheriff's Offices (SO) accounted for 37.7% (398 incidents), while other agencies contributed smaller shares: Iowa Department of Public Safety (IDPS) at 2.8%, Iowa Department of Natural Resources Parks (IDNR Parks) at 0.7%, Conservation Officers (Cons), Iowa Department of Transportation Motor Vehicle Enforcement (IDOT MVE), and Fairground Law Enforcement (LE) each under 0.57%. This distribution highlights the significant involvement of local law enforcement, particularly PDs and SOs, in ensuring rapid AED access and deployment across Iowa.

RESPONDING LAW ENFORCEMENT AGENCIES

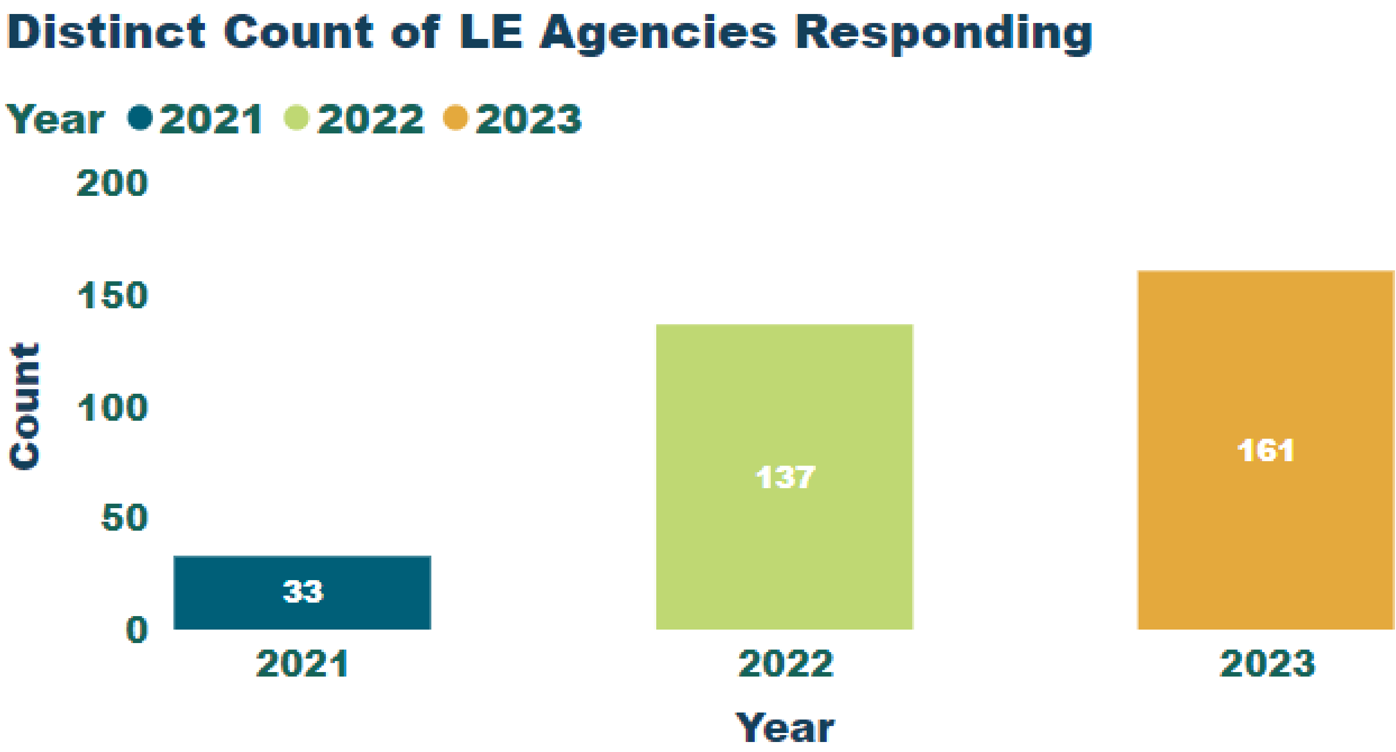


Figure 9: Unique Law Enforcement Agencies Responding to Cardiac Arrest Calls

Throughout the First Responder AED project period (June 2021 to December 2023), a total of 196 unique law enforcement (LE) agencies responded to cardiac arrest calls. The number of agencies involved increased significantly each year:

- 2021: 33 agencies participated.
- 2022: 137 agencies participated.
- 2023: 161 agencies participated.

This year-over-year growth reflects the expanding reach and engagement of LE agencies in responding to cardiac arrests, demonstrating the project's success in fostering widespread participation across the state.

Demographics

DEPLOYMENTS BY AGE GROUP

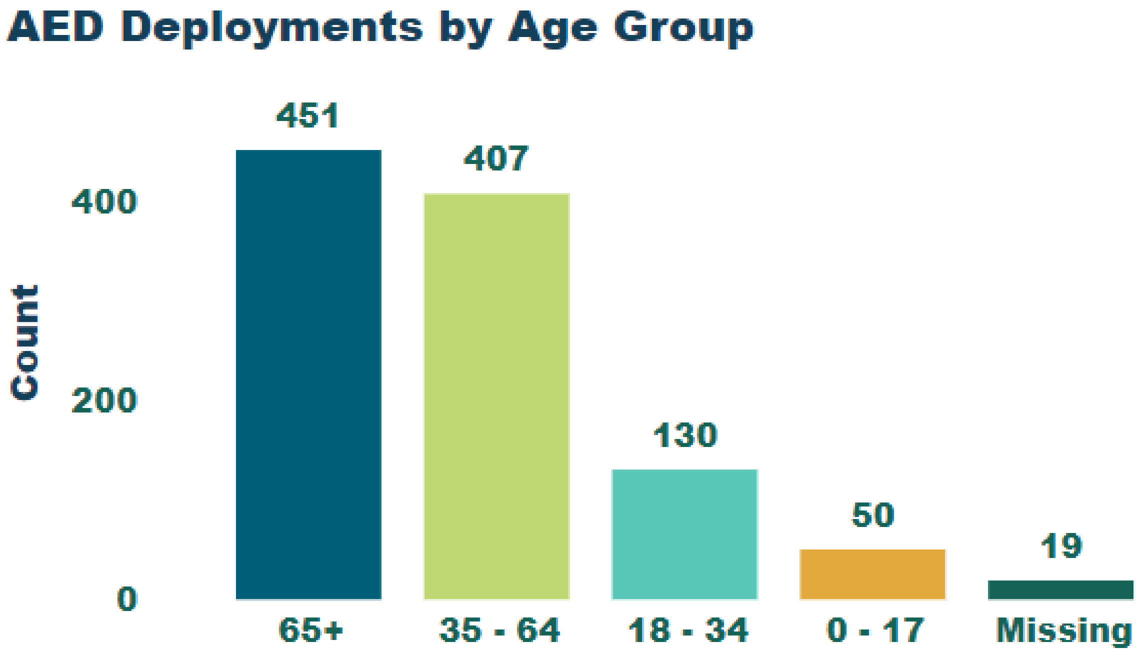


Figure 10: Deployments by Age Group

Most AED deployments occurred among older populations. Patients aged 65+ accounted for 42.67% of all deployments, making them the most frequently targeted group. Those aged 35-64 followed, representing 38.51% of deployments, showing significant AED usage in middle-aged adults.

Younger groups saw fewer interventions. The 18-34 age group represented 12.30% of AED deployments, while patients aged 0-17 made up just 4.73%. Cases with missing age data comprised 1.80% of deployments.

These data illustrate the concentration of AED usage in older adults, reflecting their higher risk for cardiac events, but also highlight that a range of ages benefit from AED interventions.

DEPLOYMENTS BY GENDER

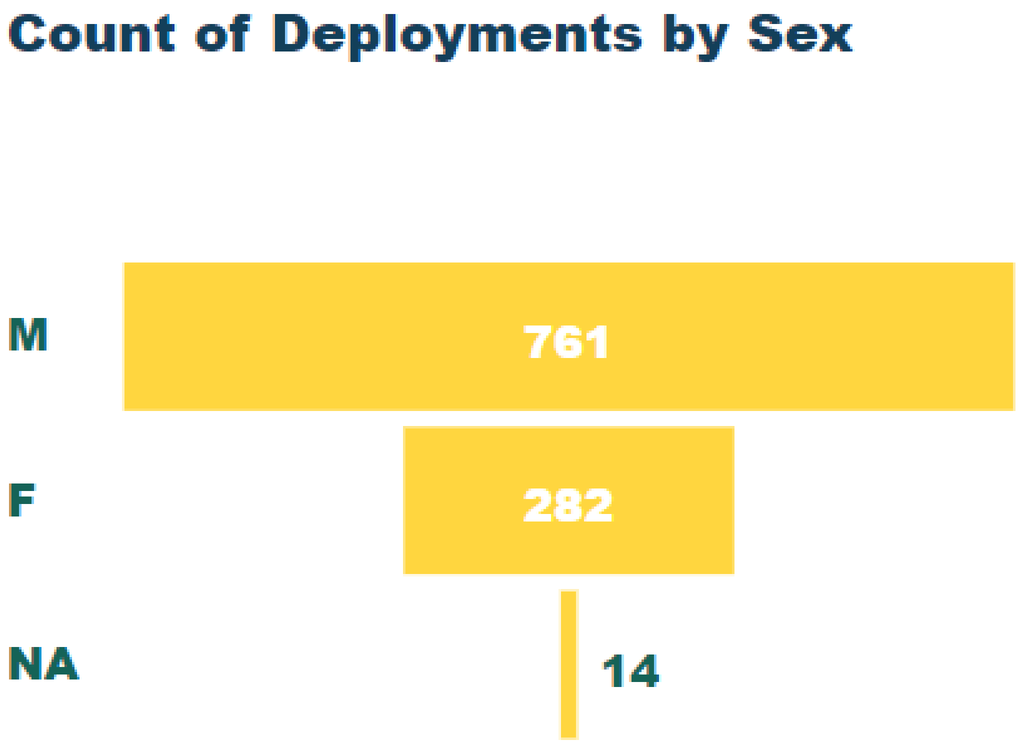


Figure 11: Deployments by Gender

The distribution of AED deployments by patient gender indicates a significant predominance of male patients, who accounted for 72.0% of all deployments with a total of 761 cases. Female patients comprised 26.7% of the total, totaling 282 deployments. Additionally, cases with missing gender data represented a small fraction, at 1.32% with 14 deployments.

These figures underscore the disparity in AED usage between genders, with males receiving a substantially higher proportion of interventions. This trend may warrant further investigation to understand the underlying factors contributing to these differences in AED deployment rates.

URBANICITY

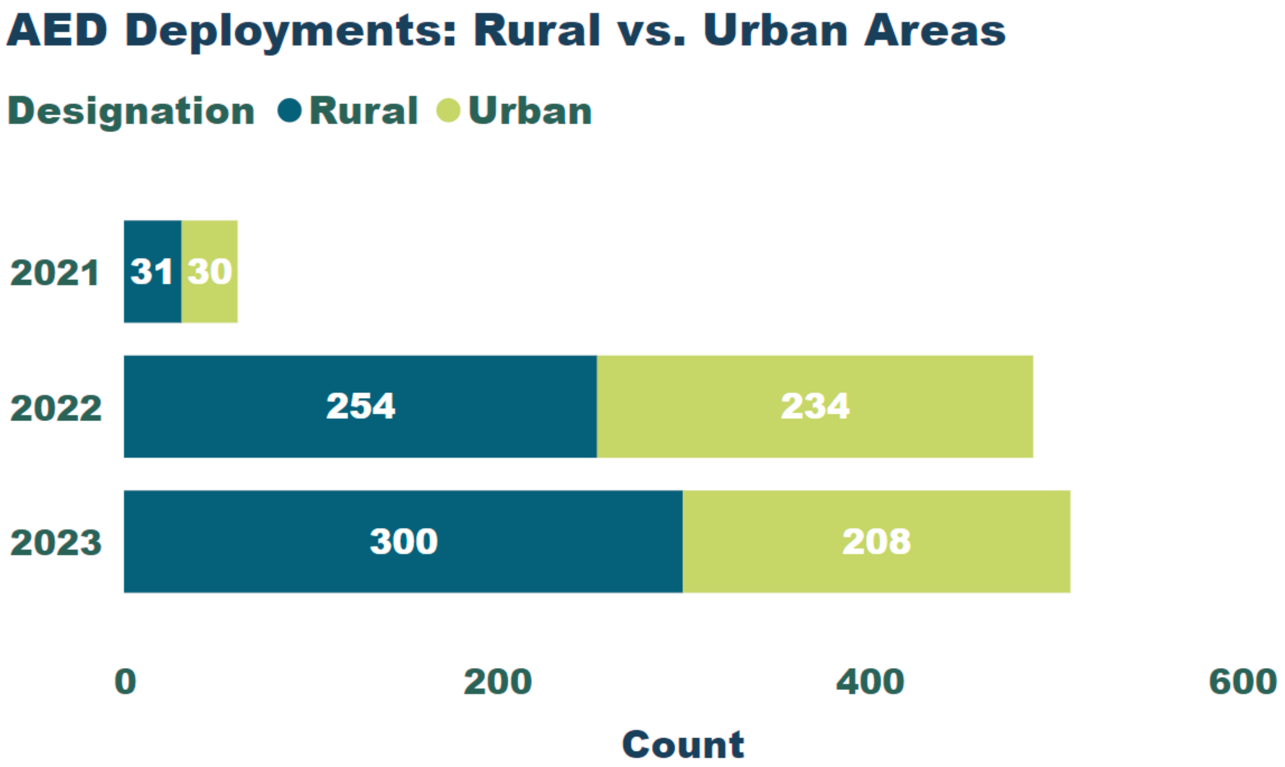


Figure 12: AED Deployments by Urbanicity of Location

From 2021 to 2023, AED deployments in rural areas consistently outpaced those in urban regions. In 2021, rural incidents accounted for 50.8% of deployments (31 incidents), nearly equal to urban at 49.2% (30 incidents). This trend continued in 2022, with rural areas comprising 52.0% (254 incidents) and urban areas 47.9% (234 incidents). By 2023, rural deployments significantly increased to 59.1% (300 incidents), while urban deployments dropped to 40.9% (208 incidents).

This trend underscores the growing importance of AED access in rural areas, where timely intervention is critical given longer EMS response times compared to urban settings. These data highlight the program's impact in addressing rural-urban disparities in emergency cardiac care.

Estimating Survival

OVERALL SURVIVAL

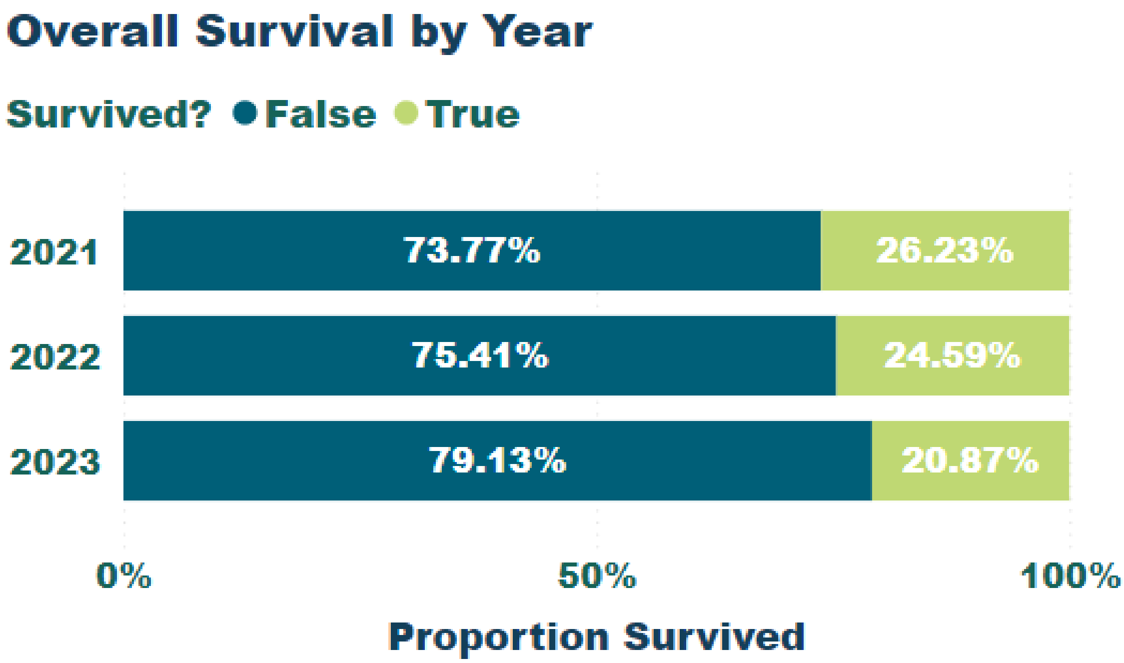


Figure 13: Overall Survival by Year

The annual breakdown of survival outcomes provides insight into the effectiveness of AED deployments over the project period. In 2021, 45 patients did not survive, while 16 patients (26.2%) survived out of 61 total AED interventions. By 2022, the total interventions increased significantly, with 368 non-survivors and 120 survivors, yielding a survival rate of 24.6%. In 2023, 402 patients did not survive, while 106 survived, resulting in a survival rate of 20.87%. The overall survival rate for the project from 2021 through 2023 is 22.89%. Please refer to the Estimating Survival section for more information about the definition of "survival."

Although the overall number of AED deployments increased each year, the proportion of patients who survived remained consistent, with a slight decrease in survival rate in 2023 compared to 2022. These data highlight the continued need for rapid AED access, improved training, and public awareness to maintain or improve survival outcomes in out-of-hospital cardiac arrest cases.

SCENE SURVIVAL

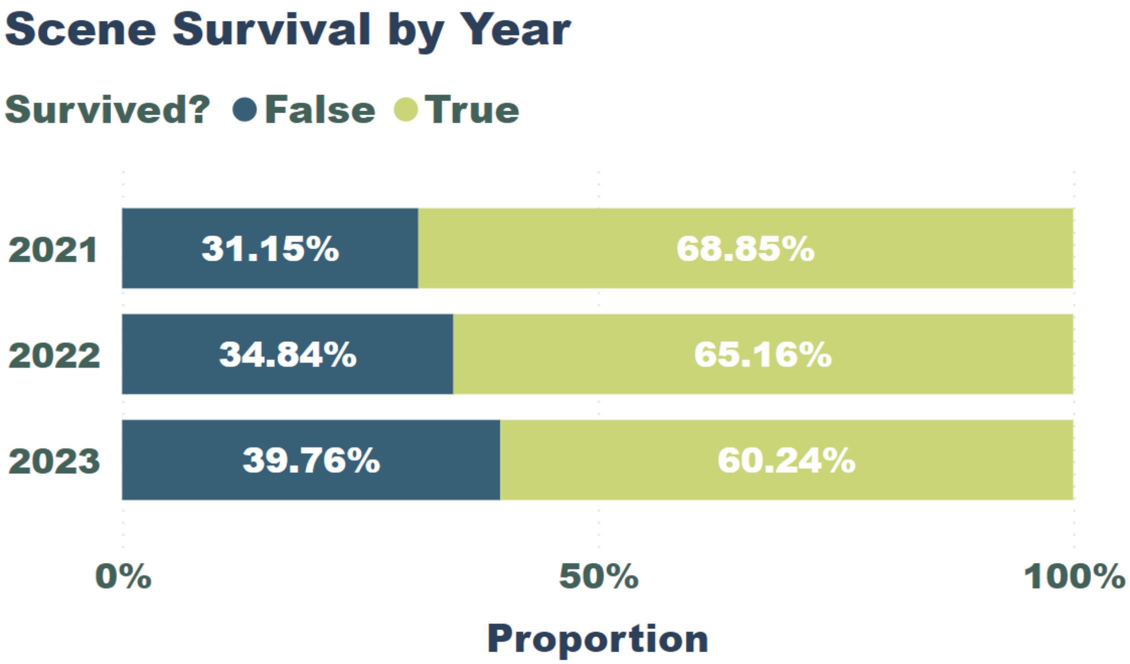


Figure 14: Scene Survival by Year

The data on scene survival, which reflects whether patients survived the immediate AED intervention at the scene of the cardiac arrest, demonstrate positive outcomes over the three-year period. In 2021, 42 patients survived the scene, while 19 did not. By 2022, the number of scene survivors increased to 318, while 170 patients did not survive the scene. Similarly, in 2023, 306 patients survived the scene, with 202 fatalities recorded.

These data show that scene survival rates consistently decreased each year, with most patients surviving the initial AED intervention. A preponderance of scene survivors across the project period highlights the critical role of AEDs in stabilizing patients during out-of-hospital cardiac arrest.

CUMULATIVE ESTIMATION OF SURVIVAL

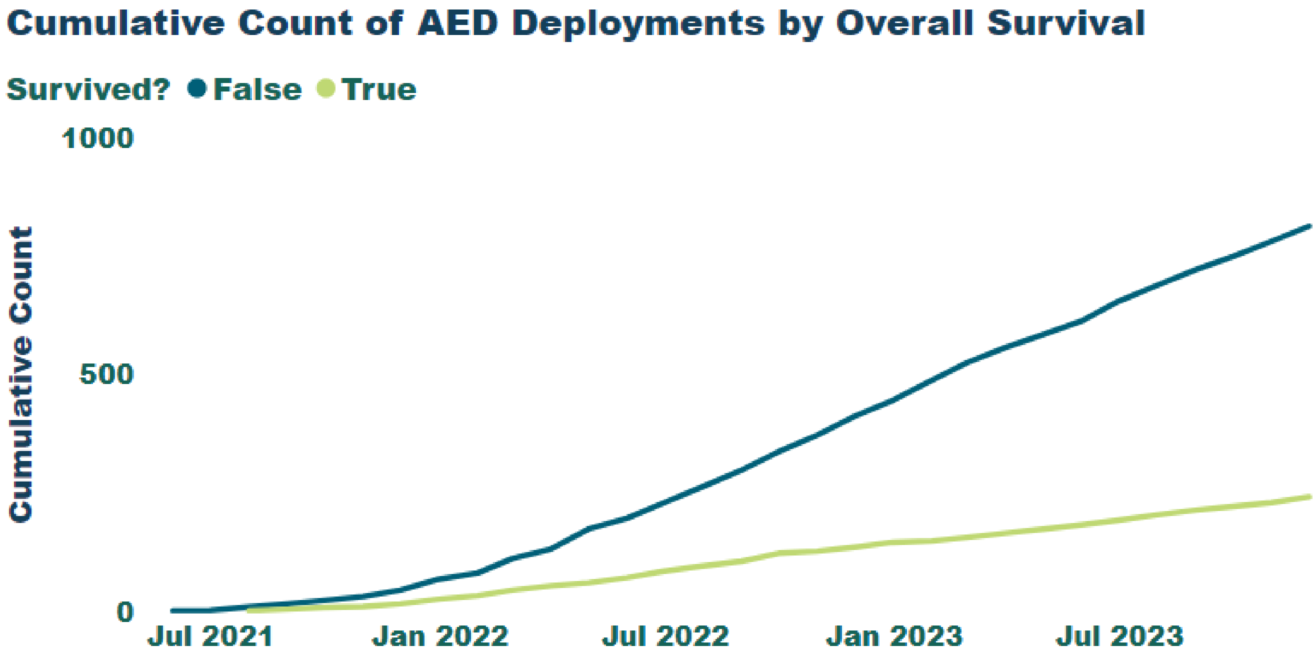


Figure 15: Cumulative Count of AED Deployments with Survival Data

The time series data on cumulative AED deployments from June 2021 to December 2023 reveal significant trends in both deployment counts and patient survival outcomes. Starting with one deployment in June 2021, the cumulative count rose steadily over the project period, reaching 1,057 by December 2023.

Survival data indicate that a notable proportion of patients survived AED interventions. For instance, in the early months of the program, the cumulative counts included survival cases, such as in October 2021, where there were 8 survivors among 23 total deployments. This pattern of increasing survival outcomes continued, with December 2023 recording 242 survivors (22.89%) and 815 decedents (77.11%), out of 1,057 total AED deployments.

Throughout this period, there was a consistent increase in both the cumulative count of AED deployments and the number of patients who survived, illustrating the effectiveness of the program. The data underscores the positive impact of AED availability and the critical importance of rapid intervention in improving survival rates for cardiac arrest patients.

SURVIVAL BY AGE GROUP

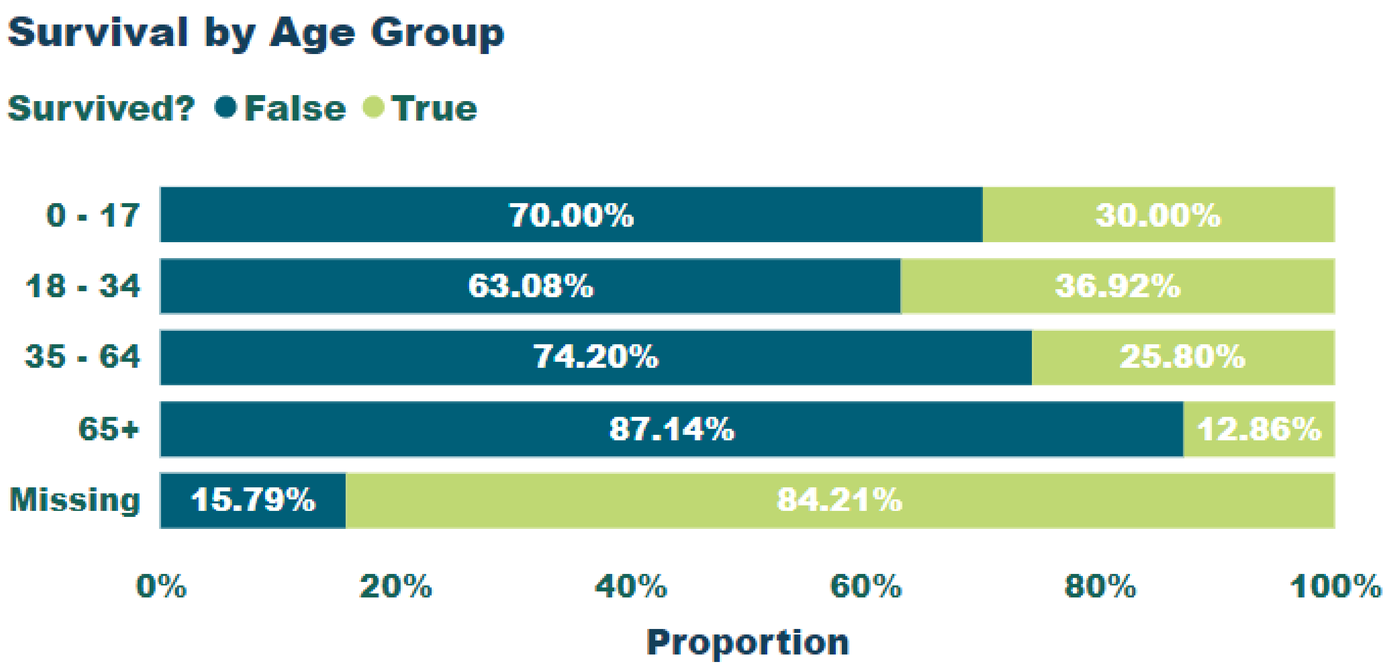


Figure 16: Survival by Age Group

The data on survival by age group offer insights into how age impacts AED intervention outcomes. For patients aged 0-17, 15 survived, while 35 did not, yielding a survival rate of approximately 30%. Among the 18-34 age group, 48 survived, and 82 did not, resulting in a survival rate of around 36.9%.

In the 35-64 age group, 105 patients survived, while 302 did not, giving a survival rate of 25.8%. The 65+ age group had the lowest survival rate, with 58 survivors and 393 non-survivors, translating to a survival rate of about 12.9%. For cases with missing age data due to a small count, only the proportions are reported above. The significance of the missing values is limited due to small sample size.

These data highlight the importance of age as a factor in cardiac arrest survival, with younger patients generally exhibiting higher survival rates, while older patients face significantly poorer outcomes.

SURVIVAL BY GENDER

Survival by Gender

Counts are Deployments

Survived?	False		True	
Sex	Count	Proportion	Count	Proportion
M	589	77.40%	172	22.60%
F	225	79.79%	57	20.21%

Table 2: Survival Rates by Gender

Survival rates varied by gender in AED deployments. Among male patients, 77.4% did not survive, while 22.6% survived. Similarly, for female patients, 79.8% did not survive, while 20.2% survived. This indicates that males and females experienced similar survival rates following AED deployments.

For patients whose gender was not recorded, 85.7% survived, and 14.3% did not. While the small sample size for the "NA" category makes it difficult to draw broad conclusions, these figures suggest that survival outcomes can vary when specific demographic details are unavailable. Counts for the NA group are excluded to protect confidentiality given small counts in the subgroup.

Overall, while both males and females experienced comparable survival rates, these data underscore the importance of consistent demographic recording and further investigation into whether gender-specific factors could influence outcomes.

SURVIVAL BY CALL TYPE

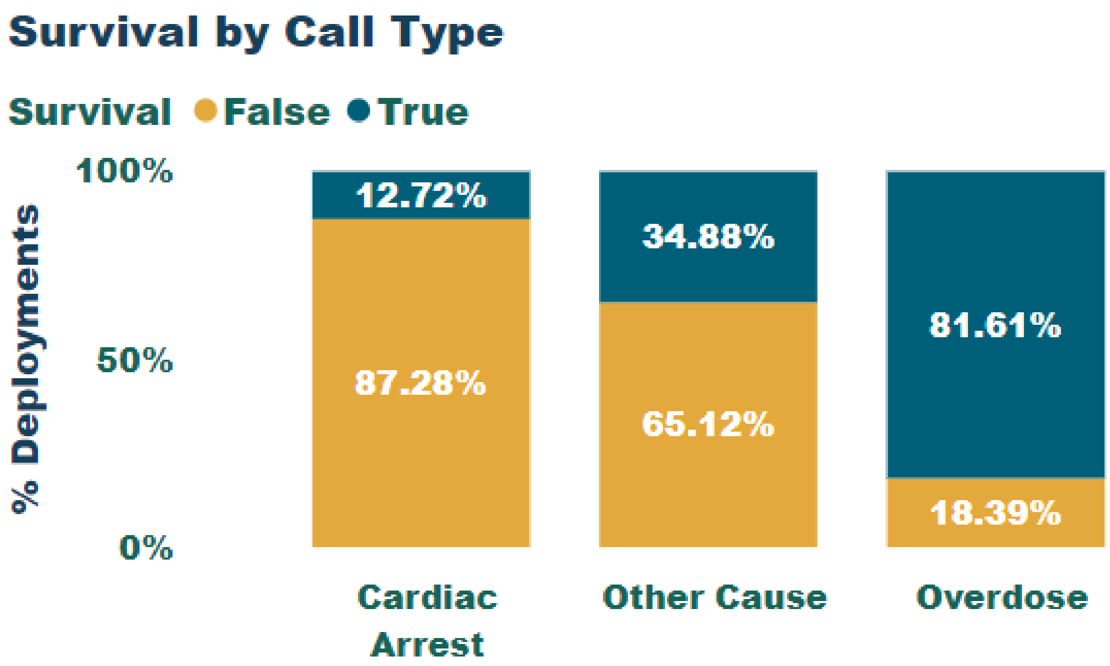


Figure 17: Overall Survival by Call Type

In the FRAED project, LEOs were called out to respond to a person with a cardiac arrest emergency. Upon receipt of the AED response data, BEMTS was able to classify these calls in three clusters a) cardiac arrest, b) other cause (including injuries), and c) overdose. The data on AED deployments and overall survival by call type provide insights into how survival outcomes vary depending on the nature of the incident. For cardiac arrest cases, there were 659 non-survivors and 96 survivors, indicating a survival rate of approximately 12.7% for these cases. For incidents classified as "Other Cause," 141 patients did not survive, while 74 survived, giving a higher survival rate of around 34.4%.

Of note, overdose cases showed a notably high survival rate, with 71 survivors compared to 16 non-survivors, yielding an impressive survival rate of approximately 81.6%.

These statistics underscore the importance of context in survival outcomes. While cardiac arrest presents the most frequent need for AED deployment, non-cardiac and overdose-related incidents appear to offer better survival prospects, highlighting the diverse applications and benefits of AEDs across different emergency situations.

Factors Predictive of Scene Survival

Logistic Regression Model Analysis of First Responder AED Data

Logistic regression is a statistical technique that models the probability of a specific outcome (event) as influenced by various predictors. Here, it is used to predict the likelihood of a patient expiring at the scene when an Automated External Defibrillator (AED) is used by law enforcement. The model estimates the "log odds" of this outcome.

LOG ODDS

Logistic regression calculates the log odds of an event (here, patient expiring). "Log odds" is a mathematical transformation that allows us to predict binary outcomes (like survival vs. non-survival) by estimating the likelihood of each.

ODDS RATIOS (OR)

After transforming log odds back to a regular scale, we interpret it as an odds ratio (OR). An OR > 1 suggests an increase in odds of the event occurring with each unit increase in the predictor, while OR < 1 suggests a decrease.

CHANGE IN ODDS

This is often expressed as a percentage, showing how much the odds increase or decrease. For example, if an OR is 1.06, the odds of the event increase by 6% with each additional unit of that predictor.

P-VALUES AND STATISTICAL SIGNIFICANCE

P-values help determine if a predictor's impact on the outcome is statistically significant. A low p-value (typically < 0.05) indicates that the predictor significantly impacts the outcome.

Model Type

This model is a binomial logistic regression predicting whether a patient expired on scene. The outcome variable is patient scene expiration, modeled against a range of factors:

- **Time from call to patient contact** and **total AED usage time** gauge response and intervention duration.

- **Patient sex** and **Patient age in years** account for demographic influences.

- **Urbanicity** represents urban or rural location.

- **Witnessed event** and **bystander CPR** variables capture situational factors impacting survival.

- **Weekday/weekend**, **day of the week**, and **season** add temporal context to the model.

This setup enables estimating the odds of on-scene expiration based on patient, situational, and time-related predictors.

Predictors in the Model

NON-STATISTICALLY SIGNIFICANT PREDICTORS

The following predictors had high p-values, indicating that they do not significantly alter the odds of patient expiration at the scene when AEDs are used by law enforcement.

Total Time AED Used: The odds ratio was 0.995 [95% CI: 0.967, 1.02], with a p-value of 0.71. This suggests that the total time an AED was actively used did not significantly change the odds of patient expiration, implying that total AED application time does not critically affect survival odds in these cases.

Patient Sex Male: The odds ratio was 0.965 [95% CI: 0.715, 1.31], with a p-value of 0.819. This indicates that gender differences do not meaningfully influence the likelihood of patient expiration when an AED is used, showing that males and females have similar survival outcomes in this context.

Urbanicity (Urban/Rural): The odds ratio for Urban designated areas was 0.897 [95% CI: 0.683, 1.18], with a p-value of 0.87. Location type (urban vs. rural) does not significantly impact patient survival odds, suggesting uniformity in outcomes across different geographic settings.

Bystander CPR: The odds ratio was 0.831 [95% CI: 0.632, 1.09], with a p-value of 0.185. This suggests that bystander CPR before law enforcement arrival does not significantly alter the odds of patient expiration, which may reflect either variability in bystander CPR quality or insufficient sample size.

Season: Comparisons across seasons (Spring, Summer, Fall, Winter) also showed non-significant changes in the odds of patient expiration, with p-values 0.636 or greater. This suggests that the season of the year does not significantly impact survival in AED-assisted emergencies.

Days of the Week: No specific day of the week showed a statistically significant effect on the likelihood of patient expiration, with all p-values above 0.05. This indicates that the day of the week when the incident occurs does not affect the probability of patient expiration.

Weekday/Weekend: No specific part of the week (weekday or weekend) showed a statistically significant effect on the likelihood of patient expiration, with all p-values above 0.05. This indicates that the week part when the incident occurs does not affect the probability of patient expiration.

STATISTICALLY SIGNIFICANT PREDICTORS

The following predictors exhibited statistically significant impacts on the likelihood of patient expiration, highlighting specific factors that meaningfully alter survival odds in AED-assisted emergency responses. It is important to understand that these model outputs were achieved while controlling for each of the variables below and including those named above.

Time from Call to Patient: Each additional minute until law enforcement arrives and begins AED use is associated with a 5.72% increase in the odds of patient expiration (OR = 1.06 [95% CI: 1.03, 1.09], $p < 0.001$). This finding underscores the critical importance of rapid response times, where each minute delay significantly reduces the likelihood of survival.

Patient Age in Years: For each additional year of patient age, the odds of expiration at the scene increase by approximately 1.74% (OR = 1.02 [95% CI: 1.01, 1.02], $p < 0.001$). This aligns with existing literature indicating that older patients are at higher risk of poor outcomes in cardiac arrest scenarios, likely due to pre-existing health conditions or decreased physiological resilience.

Witnessed Arrest: The presence of witnesses during the cardiac event significantly decreases the odds of patient expiration by 64.53% (OR = 0.36 [95% CI: 0.269, 0.465], $p < 0.001$). This suggests that witnesses play a crucial role, likely through faster emergency calls and possible immediate actions that can improve patient survival prospects.

Detailed Analysis of Predictor Impact

The model indicates that certain situational and demographic factors significantly influence the survival chances of cardiac arrest patients when AEDs are used by law enforcement. Specifically, faster response times, younger age, and the presence of witnesses stand out as influential. Although other factors like total AED application time, gender, day of the week or weekend, bystander CPR, annual season, and geographic setting (urban/rural) were included in the model, these did not show significant predictive power within this sample.

The non-significant impact of total AED time and bystander CPR could indicate that in the context of law enforcement AED use, initial response time and presence of witnesses are more critical than the duration of AED application. Meanwhile, demographic aspects such as gender or geographic factors appear not to influence survival outcomes, suggesting that cardiac arrest incidents may have relatively uniform survival factors across different populations in these emergency settings.

Model Limitations

The model's performance metrics indicate modest explanatory power, with pseudo-R^2 values across methods—McFadden (0.084), Cox-Snell (0.105), Nagelkerke (0.143), Aldrich-Nelson (0.100), and Veall-Zimmerman (0.176)—all showing low predictive strength. Although the model captures some variation in patient outcomes, the small pseudo-R^2 values highlight limited explanatory utility, suggesting it may benefit from additional, relevant predictors or a different modeling approach to improve accuracy.

The logistic regression model has limitations affecting its interpretability and reliability. Interaction terms were not utilized in the model and may help better model the relationships of the predictors to scene survival. Low pseudo-R^2 values suggest limited explanatory power, and multicollinearity may obscure true predictor effects. The lack of access to important variables like initial rhythm, whether the patient achieved return of spontaneous circulation (ROSC), and health status, handling class imbalance, and assumptions of effect homogeneity and independence further limit model accuracy. Relying on p-values without assessing clinical relevance also risks overstating significance. Addressing these issues through future research using alternative methods could enhance predictive performance for patient outcome analysis.

Conclusion

This logistic regression model provides a clear understanding of factors affecting patient survival odds in cases where law enforcement officers apply AEDs during emergencies. Key findings emphasize the necessity of swift response times and the potential benefits of witness presence, while also underscoring that certain demographic and situational factors, such as gender or day of the week, appear irrelevant in predicting patient outcomes in the context of this specific dataset.

Ultimately, the significant predictors—response time, patient age, and witnessed events—suggest areas for targeted improvement in AED program policies, emphasizing faster response times and potential training for bystanders. Insights from this analysis can guide further training, resource allocation, and public education efforts to optimize survival outcomes in AED-assisted cardiac emergencies handled by law enforcement.

Literature Review

Out-of-hospital cardiac arrest (OHCA) remains a critical global public health challenge, with survival rates varying significantly depending on a range of factors, including bystander intervention, emergency medical response, and patient-specific characteristics. The complex nature of OHCA outcomes has prompted extensive research into the effectiveness of various interventions aimed at improving both short- and long-term survival rates. A growing body of literature has focused on pre-hospital factors such as the timing and quality of cardiopulmonary resuscitation (CPR), the role of advanced life support techniques, and the impact of defibrillation on survival.

Additionally, studies have explored the influence of system-level factors, including the availability of specialized emergency medical personnel, time to definitive care, and post-resuscitation support in hospital settings. Understanding how these interventions contribute to OHCA outcomes is crucial for refining current clinical practices and guiding future policy developments. In this section, we review key findings from the literature on OHCA interventions, examining the predictors of survival, the role of emergency medical services (EMS) personnel, and the effectiveness of both basic and advanced life-saving measures. Through this review, we aim to synthesize the current evidence on intervention strategies that contribute to improved survival and functional recovery in OHCA patients.

Out of Hospital Cardiac Arrest Survival

Pemberton et al. (2023) aimed to identify predictors of long-term survival outcomes in adults experiencing out-of-hospital cardiac arrest (OHCA) of presumed cardiac origin. This retrospective cohort study linked three Queensland-based databases: the OHCA Registry, the Hospital Admitted Patient Data Collection, and the Registrar General Death Registry. Adult patients (18 years and older) who had an OHCA between 2002 and 2014 and received attempted resuscitation were included. Four survival outcomes were analyzed: 1) No return of spontaneous circulation (ROSC) sustained to the emergency department (ED); 2) Survival <30 days; 3) Survival between 30 and 364 days; and 4) Survival of 365+ days. Multinomial logistic regression revealed key predictors of 365+ days survival, including an initial shockable rhythm, bystander-witnessed events with CPR, paramedic-witnessed events, intubation, time of day, and attendance by Critical Care Paramedics (CCP). The findings suggest CCP attendance may enhance long-term outcomes due to their advanced clinical skills and experience.

Møller et al. (2020) examined the impact of population density on bystander cardiopulmonary resuscitation (CPR) and survival outcomes in out-of-hospital cardiac arrest (OHCA) cases. Data from the Danish Cardiac Arrest Registry (2001–2013) were used to classify OHCAs based on four population density categories. High population density areas had shorter EMS response times (10 minutes vs. 14 minutes in low-density areas) but lower rates of bystander CPR (34.3% vs. 45.1%). Thirty-day survival was higher in areas with very high population density (10.2% vs.

5.3% in low-density areas), even in cases with bystander CPR and response time <10 minutes. Logistic regression analyses revealed lower odds for bystander CPR in high-density areas (OR 0.55, 95% CI [0.46–0.66], $p < 0.01$) and higher odds for 30-day survival (OR 2.78, 95% CI [1.95–3.96], $p < 0.01$) compared to low-density areas. These results underscore the importance of understanding how population density impacts OHCA outcomes, which may guide future pre-hospital care strategies.

Oving et al. (2020) explored the impact of cumulative comorbidity burden, measured by the Charlson Comorbidity Index (CCI), on survival outcomes after out-of-hospital cardiac arrest (OHCA). Data from 2510 adult patients in a prospective Dutch OHCA registry (2010–2014) were analyzed using logistic regression. CCI was significantly associated with a reduced overall survival rate (OR 0.71; 95% CI 0.61–0.83; $p < 0.01$). While CCI did not impact pre-hospital survival (OR 0.96; 95% CI 0.76–1.23; $p = 0.92$), high CCI significantly lowered in-hospital survival (OR 0.41; 95% CI 0.27–0.62; $p = 0.01$). The Nagelkerke test revealed that the relative contributions of CCI to pre-hospital and in-hospital survival were 1.1% and 8.1%, respectively. These findings suggest that while comorbidities minimally affect pre-hospital survival, they play a critical role in reducing survival during the in-hospital phase, emphasizing the need for consideration in resuscitation planning and patient care discussions.

Schultz et al. (2020) analyzed survival outcomes for patients who experienced out-of-hospital cardiac arrest (OHCA) due to ST-segment elevation myocardial infarction (STEMI) as identified by paramedics in Queensland, Australia, between 2013 and 2017. A total of 287 patients were included, with high survival rates reported: 77% survived the initial OHCA event, and 75% survived to discharge. Key predictors of survival included the presence of an initial shockable rhythm (adjusted OR 8.60, 95% CI 4.16–17.76; $p < 0.001$) and the administration of prehospital medication for percutaneous coronary intervention (adjusted OR 2.54, 95% CI 1.17–5.50; $p = 0.020$). These factors also significantly increased the odds of survival to hospital discharge, with ORs of 13.74 (95% CI 6.02–31.32; $p < 0.001$) and 6.96 (95% CI 2.50–19.41; $p < 0.001$), respectively. Additionally, prehospital fibrinolytic medication was associated with improved survival in a subgroup analysis. This study highlights the high salvageability of OHCA patients in the context of paramedic-identified STEMI and emphasizes the importance of early intervention.

Law Enforcement AED Outcomes

Lupton et al. (2024) examined the outcomes of out-of-hospital cardiac arrest (OHCA) cases when law enforcement (LE) arrived before emergency medical services (EMS), focusing on the impact of LE-provided cardiopulmonary resuscitation (CPR) and automated external defibrillator (AED) application. The retrospective analysis included 2,569 adult non-traumatic OHCA cases from 2018 to 2021. The primary outcome was functional survival, defined by a Cerebral Perfusion Category score of ≤2. Key comparisons were made between cases where LE provided no care, CPR-only, or both CPR and AED (Ideal Care) before EMS arrival. In patients without bystander CPR, LE Ideal Care was associated with significantly improved odds of functional survival (adjusted OR 2.01, 95% CI 1.06–3.81). However, no significant survival differences were observed in patients already receiving bystander CPR or in cases where LE provided no care or CPR without AED use. The study suggests that LE intervention before EMS arrival, particularly involving both CPR and AED, can improve outcomes in OHCA patients not receiving prior bystander CPR.

Dowker et al. (2024) investigated the involvement of police in out-of-hospital cardiac arrest (OHCA) scenarios across various emergency medical systems in Michigan. It aims to explore the variations in police roles during OHCA responses and identify organizational factors that influence these variations. Using a qualitative multisite case study design, the research included semi-structured interviews and focus groups with 160 key informants from various public safety sectors, including telecommunicators, firefighters, police officers, emergency medical services, and hospital personnel. The analysis revealed that police typically serve four main on-scene roles in OHCA situations: early responders, resuscitation team members, security personnel, and information gatherers. Additionally, they occasionally take on supplementary roles such as telecommunicators and cardiac arrest educators.

Dowker et al. (2024) identified several factors that affect police engagement in OHCA response, including agency administrative structure, available resources, organizational culture, medical training, response policies, the nature of the response environment, and relationships with other emergency stakeholders. The findings suggest that police play significant roles in OHCA response, shaped by various site-specific factors, and highlight the need for further research to optimize police participation in such emergencies.

Gaisendrees et al. (2023) discuss the Minnesota First-Responder Automated External Defibrillator (AED) Project, which aims to improve survival rates in out-of-hospital cardiac arrest (OHCA) cases by enhancing AED availability. The project, funded by an $18.8 million grant from the Helmsley Charitable Trust, focuses on providing law enforcement first responders with AEDs to reduce the time to first shock, which is critical for improving survival in cardiac arrests with an initial shockable rhythm. A baseline assessment of AED needs was conducted through a questionnaire distributed to law enforcement agencies across Minnesota in 2021, revealing a requirement for 8,300 AEDs over three years (2022–2025). The survey received a 77% response rate from 358 agencies. By 2023, 4,769 AEDs had been distributed across 237 sites. The project underscores the importance of equipping first responders with AED systems to enhance statewide AED coverage and ultimately increase the chances of survival following OHCA.

Thompson et al. (2024) investigated gender disparities in defibrillator practices during out-of-hospital cardiac arrest (OHCA), focusing on automated external defibrillator (AED) usage before Emergency Medical Services (EMS) arrival and the time to initial EMS defibrillation. Conducted as a secondary analysis of the Portland Cardiac Arrest Epidemiologic Registry from 2018 to 2021, the research included adult non-traumatic OHCA cases treated by EMS, excluding EMS-witnessed arrests. The primary outcomes assessed were pre-EMS AED application rates and the time from EMS arrival to the first defibrillation among patients with a shockable rhythm who did not receive AED application prior to EMS arrival.

Among 3,135 adult cases analyzed in Thompson et al. (2024), 3,049 had complete data, with 1,011 (33.2%) being women. The results revealed that the adjusted odds of pre-EMS AED application were significantly higher for men (adjusted odds ratio [95% CI]: 1.40 [1.05–1.86]). This trend persisted for law enforcement AED applications (1.89 [1.16–3.07]), while lay bystander AED application showed no significant difference (1.19 [0.83–1.71]). Furthermore, women who remained in arrest upon EMS arrival had a longer delay to initial defibrillation compared to men (+0.81 minutes [0.22–1.41 minutes]).

In conclusion, the Thompson et al. (2024) highlighted significant gender disparities in pre-EMS AED application and delays in initial defibrillation, indicating that women with OHCA face additional barriers to timely treatment compared to men.

Summary

Research on out-of-hospital cardiac arrest (OHCA) emphasizes the complexities surrounding survival rates, influenced by various factors such as bystander intervention, emergency medical response, and patient characteristics. Key studies have identified predictors of survival, highlighting the importance of interventions like bystander CPR, advanced life support, and the timely use of automated external defibrillators (AEDs). For instance:

- Pemberton et al. (2023) identified that factors such as initial shockable rhythm and the presence of Critical Care Paramedics significantly influence long-term survival.
- Møller et al. (2020) demonstrated the impact of population density on bystander CPR rates and survival outcomes, revealing that while high-density areas have quicker EMS responses, they also show lower bystander CPR rates.
- Oving et al. (2020) found that a higher comorbidity burden negatively affects survival, especially during the in-hospital phase, while Schultz et al. (2020) emphasized the importance of early intervention in cases of STEMI.

Research focusing on law enforcement's role in OHCA responses indicates that police can significantly influence outcomes when they provide early intervention, including CPR and AED application. Lupton et al. (2024) found that police involvement improved survival odds, particularly in cases without prior bystander CPR. Dowker et al. (2024) explored variations in police roles across different jurisdictions, identifying organizational factors affecting their engagement.

FUTURE RESEARCH DIRECTIONS

To extend the current literature on OHCA survival and law enforcement AED practices, several research avenues should be pursued:

1. Standardization of Police Training: Investigate the impact of standardized training programs for police officers on AED usage and CPR delivery. Understanding best practices could enhance the quality and consistency of emergency care.
2. Longitudinal Studies on Outcomes: Conduct longitudinal studies examining long-term survival rates and functional outcomes of OHCA patients who received police interventions compared to those who did not. This research could provide valuable insights into the efficacy of law enforcement involvement.
3. Exploration of Community Awareness: Research the effects of community-level education and awareness campaigns on AED usage rates and bystander CPR, particularly in areas with high OHCA incidences. This could help identify barriers to engagement and potential strategies to increase participation.
4. Analysis of Gender Disparities: Further investigate the factors contributing to gender disparities in AED usage and time to defibrillation, as identified by Thompson et al. (2024). Understanding these barriers can inform interventions aimed at improving outcomes for women experiencing OHCA.
5. Integration of Technology: Explore the role of technology, such as mobile apps that direct bystanders to nearby AEDs or alert police officers to OHCA events, in improving response times and survival rates.

By addressing these gaps, future research can enhance the understanding of the critical role law enforcement plays in OHCA scenarios and contribute to the development of more effective interventions aimed at improving survival rates in these emergencies.

Technical Notes

While many consumers of health statistics may be aware of the information in this report, others may not fully understand the limitations of the data. This section provides definitions and important details about the nature and methods used to calculate key metrics referenced within the report.

Nature of the Data

In this report, all incidents occurred within the state of Iowa. The granularity of geolocation possible in this report is down to the city or county level, whichever was available in the raw data. Generalizations made about data within this report should be made with caution outside of the state of Iowa. Given that some cities were not represented in the data for this project, and some counties and regions were not as well represented, caution must be used when interpreting results and comparing regions within Iowa. Additionally, not all law enforcement agencies participated in this grant program. Thus, the findings of this study may not generalize well to all types of law enforcement agencies or jurisdictions. Using data from this report to compare cities, counties, or regions is not recommended.

Quality of the Data

Most datasets contain missing values, outliers, or errors to some degree due to data entry issues, limitations of data collection software, and equipment failure. Caution is taken by the epidemiologist to deal with data quality issues within the AED dataset and the ImageTrend Elite registry used to provide data for this report. Where possible, the epidemiologist attempts to deal with missing values using imputation methods that favor a deductive approach. This means that if the true value for a missing cell can be deduced from other existing information in the data, imputation is used, else the value is left missing. The raw data are never modified, and all imputations happen on copies of the raw data taken into memory by statistical computing software.

For numeric values that suffer from missingness, the BEMTS epidemiologist conducts two cleaning steps to deal with missingness and outliers. When necessary, continuous variables are cleaned via mean or median imputation for missing values and then winsorization to deal with outliers beyond the 95th and 5th percentiles.

Limitations Associated with Small Numbers

Counts less than six incidents reported below the state level will be masked in this report to protect patient confidentiality. When working with small numbers in statistical analysis, two primary limitations must be considered:

Small Number of Occurrences: This limitation arises when there are few instances of a particular vital event.

Small Population Size: This limitation involves calculating rates or ratios for a small population, even if the number of occurrences of the event is not inherently small.

These limitations necessitate caution when using such data, as statistical stability cannot be guaranteed under these conditions. The definition of what constitutes a "small number" can vary, but typically, occurrences fewer than 20 and populations under 100 are deemed unstable for most statistical calculations. Users must exercise judgment in determining the adequacy of their data for analysis.

Estimating Survival

The survival rate within a population is a critical metric that reflects the quality and efficacy of medical interventions, serving as a cornerstone in numerous research endeavors worldwide. In this report, the survival variable is defined with precision: a patient is considered to have survived only if they meet three key criteria. Firstly, they must survive the initial AED intervention at the scene of the cardiac arrest. Secondly, they must remain stable through the intervention in the Emergency Department (ED). Finally, the patient must also sustain their recovery during hospitalization. Consequently, unless otherwise specified, the term "survival" in this report encompasses the entire continuum of care from the scene to the hospital, indicating that the patient has successfully navigated all critical stages of treatment.

It is also essential to note that throughout this report, references to survival statistics may pertain to specific contexts, such as scene survival, which will be clearly labeled to avoid ambiguity. This level of clarity ensures that readers fully comprehend the nuances of survival data and its implications, thereby enhancing the overall understanding of the AED intervention outcomes presented herein.

Time Formulas

Time from Call to Patient: This time duration is referenced within this report and is calculated in minutes by taking the date and time of the emergency call and subtracting it from the time the unit (i.e., EMS or LEO) arrived at the patient. The formula is as follows:

$$T_{Arrival} = t_{call} - t_{patient}$$

Total Time AED Used: To calculate this time duration, the time the AED was turned on is subtracted from the time the AED was turned off and reported in minutes. See the formula below:

$$T_{AED} = t_{off} - t_{on}$$

Rate calculations: In this report, percentages are a rate per 100 and are calculated conventionally. Other rates in this report are calculated as the count for a location (e.g., city, county) divided by the corresponding population, multiplied by 10,000. Age adjustment is not done in this report as comparisons among population groups like counties are not done given that multiple geographic locations in Iowa are not represented in this project. The formula can be understood below:

$$Rate\ per\ 10{,}000 = \left(\frac{count}{population}\right) x\ 10{,}000$$

References

Centers for Disease Control and Prevention. (n.d.). Heart disease in the United States. https://www.cdc.gov/heart-disease/data-research/facts-stats/index.html

Dowker, S. R., Fouche, S., Simpson, K., Yoon, H. R., Rosbury, S. R., & Malik, S. (2024). Police involvement in out-of-hospital cardiac arrest: A qualitative exploration of law enforcement roles and contributing organizational factors. Journal of Emergency Management, 22(6). https://doi.org/10.1080/10903127.2024.2397534

Folke, F., Shahriari, P., Hansen, C. M., & Gregers, M. C. T. (2023). Recent advances in public access defibrillation: Implications for early defibrillation in out-of-hospital cardiac arrest. Current Opinion in Critical Care, 29(3), 168–174. https://doi.org/10.1097/MCC.0000000000001051

Gaisendrees, C., Jaeger, D., Kalra, R., Kosmopoulos, M., Harkins, K., Marquez, A., Hodgson, L., Kollmar, L., Bartos, J., & Yannopoulos, D. (2023). The Minnesota first-responder AED project: Aiming to increase survival in out-of-hospital cardiac arrest. Resuscitation Plus, 15, 100437. https://doi.org/10.1016/j.resplu.2023.100437

Lupton, J. R., Johnson, E., Prigmore, B., Daya, M. R., Jui, J., Thompson, K., Nuttall, J., Neth, M. R., Sahni, R., & Newgard, C. D. (2024). Out-of-hospital cardiac arrest outcomes when law enforcement arrives before emergency medical services. Resuscitation, 194, 110044. https://doi.org/10.1016/j.resuscitation.2023.110044

Martin, S., Aday, A., Almarzooq, Z., Anderson, C., Pankaj, A., Avery, C., Baker-Smith, C., Gibbs, B., Beaton, A., Boehme, A., Commodore-Mensah, Y., Currie, M., Elkind, M., Evenson, K., Generoso, G., Heard, D., Hiremath, S., Johansen, M., Kalani, R.,... Palaniappan, L. (2024). 2024 Heart disease and stroke statistics: A report of US and global data from the American Heart Association. Circulation, 149, 347–913. doi: 10.1161/CIR.0000000000001209

Meaney, P., Bobrow, B., Mancini, M., Christenson, J., Caen, A., Bhanji, F., Abella, B., Kleinman, M., Edelson, D., Berg, R., Aufderheide, T., Menon, V., & Leary, M. (2013). CPR quality: Improving cardiac resuscitation outcomes both inside and outside the hospital: A consensus statement from the American Heart Association. Circulation, 128. doi: 10.1161/CIR.0b013e31829d8654.

Møller, S., Rajan, S., Møller-Hansen, S., Kragholm, K., Ringgren, K., Folke, F., Hansen, C., Lippert, F., Køber, L., Gislason, G., Torp-Pedersen, C., & Wissenberg, M. (2020). Pre-hospital factors and survival after out-of-hospital cardiac arrest according to population density, a nationwide study. Resuscitation Plus, 4. http://dx.doi.org/10.1016/j.resplu.2020.100036

National Center for Health Statistics (2024). Multiple Cause of Death 2018–2022 on CDC WONDER Database. Accessed October 18, 2024. https://wonder.cdc.gov/mcd.html

Oving, I., van Dongen, L., Deurholt, S., Ramdani, A., Beesems, S., Tan, H., & Blom, M. T. (2020). Comorbidity and survival in the pre-hospital and in-hospital phase after out-of-hospital cardiac arrest, Resuscitation, 153, 58-64, https://doi.org/10.1016/j.resuscitation.2020.05.035

Pemberton, K., Franklin, R., Bosley, E., & Watt, K. (2023). Pre-hospital predictors of long-term survival from out-of-hospital cardiac arrest. Australasian Emergency Care, 26(2), 184-192, https://doi.org/10.1016/j.auec.2022.10.006

Schultz, B., Doan, T., Bosley, E., Rogers, B., & Rashford, S. (2020). Prehospital study of survival outcomes from out-of-hospital cardiac arrest in ST-elevation myocardial infarction in Queensland, Australia (the PRAISE study). Eur Heart J Acute Cardiovasc Care, 10(6), 616-623, doi: 10.1177/2048872620907529

Thompson, K., Smith, J., Tanski, M., Neth, M. R., Sahni, R., & Kennel, J. (2024). Gender differences in defibrillator practices in out-of-hospital cardiac arrest. Journal of Emergency Management, 22(6). https://doi.org/10.1080/10903127.2024.2394590

Tsao, C. Aday, A., Almarzooq, Z., Anderson, C., Arora, P., Avery, C., Baker-Smith, C., Beaton, A., Boehme, A., Buxton, A., Commodore-Mensah, Y., Elkind, M., Evenson, K., Eze-Nliam, C., Fugar, S., Generoso, G., Heard, D., Hiremath, S., ... Martin, S. (2023). Heart Disease and Stroke Statistics—2023 Update: A Report From the American Heart Association. Circulation, 147(8), 93-621, doi: 10.1161/CIR.0000000000001123