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Beyond the Presenting Rhythm: Estimating Shockable Rhythm at the Time of Cardiac Arrest in Out-of-Hospital Cardiac Arrest

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Abstract

Background

Out of hospital cardiac arrest (OHCA) remains a leading cause of death worldwide with survival strongly dependent on the presence of a shockable rhythm at the time of first rhythm analysis. Thus, determinants of a shockable rhythm in cardiac arrest is important.

Methods

We analysed adult non-traumatic witnessed OHCA in New South Wales from 2017–2022 with bystander CPR. We used generalised additive modelling (GAM) to estimate the probability that an OHCA in this cohort was initially shockable and to characterise how this probability varied according to age and sex.

Results

NSW Ambulance attended 45,607 during the period January 2017 through March 2022 of which 5,277 met eligibility criteria. The GAM identified significant sex-specific relationships between age, elapsed time and the probability of a shockable rhythm. The relationship between age and shockable rhythm was non-linear in males (edf 4.14, $\chi^2 = 167.2$, $p < 0.001$), whereas the relationship was approximately linear in females (edf 1.00, $\chi^2 = 51.8$, $p < 0.001$). Elapsed time was significantly associated with shockable rhythm in both males (edf 1.00, $\chi^2 = 89.3$, $p < 0.001$) and females (edf 1.88, $\chi^2 = 23.9$, $p < 0.001$), with greater evidence of non-linearity among females. At the estimated time of collapse ($t = 0$), the GAM estimated a probability of a shockable rhythm of 41% (95% CI 27–55%) among females, representing a 17% increase compared with the observed presenting shockable rhythm rate of 24%. Among males, the corresponding estimated probability was 61% (95% CI 56–67%), representing an 18% increase compared with the observed presenting rate of 43%.

Conclusions

Our modelling suggests the proportion of arrests initially presenting as shockable may be substantially higher than that observed at first EMS rhythm analysis. We conclude that presenting rhythm in OHCA is a dynamic, time-dependent phenomenon and demonstrates the potential value of GAM-based modelling for estimating the probability of a shockable rhythm at or near the time of collapse. These findings provide a more nuanced framework for understanding age and sex differences in OHCA and highlight the importance of considering the timing of rhythm assessment when interpreting epidemiological differences in shockable rhythm.

Introduction

Out-of-hospital cardiac arrest (OHCA) remains a leading cause of death worldwide (1–3), with survival strongly dependent on the presence of a shockable rhythm at the time of first rhythm analysis (4–7). Patients presenting with ventricular fibrillation (VF) or pulseless ventricular tachycardia (pVT) have substantially higher survival rates than those presenting with pulseless electrical activity or asystole (8). Consequently, considerable attention has been directed towards understanding the determinants of shockable rhythm in OHCA, including age, sex, witnessed status, arrest location (9), bystander cardiopulmonary resuscitation, and emergency medical service (EMS) response times (10).

The proportion of OHCAs with a shockable rhythm at first EMS assessment has declined over recent decades in several populations (11–13). This decline is generally interpreted as reflecting changes in the underlying epidemiology and aetiology of cardiac arrest. However, the rhythm recorded by EMS may not represent the rhythm present at the onset of cardiac arrest. In most cases, the first documented rhythm is obtained only after an interval between collapse and professional assessment, during which an initially shockable rhythm may deteriorate to pulseless electrical activity or asystole (14). Consequently, temporal trends in the rhythm recorded at EMS assessment may reflect both changes in the rhythm at the onset of cardiac arrest and changes in the evolution of rhythm before it is first documented due, for example, to longer EMS response times. Distinguishing between these processes is important when interpreting the epidemiology of shockable rhythm.

Evidence from studies examining rhythm at or immediately following the onset of sudden cardiac death suggests that the proportion of arrests initially characterised by ventricular tachyarrhythmia may be substantially higher than the proportion of shockable rhythms recorded by EMS. Early Holter monitoring studies identified ventricular tachyarrhythmias in approximately 80% of sudden cardiac deaths (15,16), while an analysis of rhythm strips from 258 witnessed OHCAs with rhythm documentation identified a shockable rhythm in 68% (17). These findings suggest that the rhythm observed at EMS arrival may substantially underestimate the proportion of arrests initiated by VF/pVT.

This distinction may also be important when interpreting sex differences in OHCA. Among the most consistent findings in the OHCA literature is that females are less likely than males to present with a shockable rhythm (18,19). Women are more likely to experience arrests in circumstances associated with delayed rhythm acquisition, including arrests occurring at home, unwitnessed collapse, and longer delays to resuscitation (18–21). Such factors may increase the interval during which an initially shockable rhythm can deteriorate before rhythm assessment. Conversely, persistent differences in shockable rhythm after adjustment for response intervals suggest that biological differences in arrhythmic susceptibility may also contribute (22). Thus, the extent to which observed sex differences reflect differences in the rhythm initiating cardiac arrest, rather than differences in rhythm evolution before EMS assessment, remains uncertain.

Age may similarly influence the relationship between the rhythm at cardiac arrest and the rhythm subsequently documented by EMS. Recent work has identified non-linear associations between age and shockable rhythm (22). However, these analyses, like most OHCA studies, rely on the rhythm

documented during the emergency response as the measure of the initial rhythm. Estimating the probability of shockable rhythm at the time of collapse could therefore provide a different perspective on the epidemiology of OHCA and clarify whether observed age- and sex-specific differences persist when the potential effect of elapsed time before rhythm assessment is considered.

We therefore used generalised additive modelling to estimate the probability of a shockable rhythm at the estimated time of cardiac arrest from rhythms documented following EMS arrival. By modelling the relationship between elapsed time and observed rhythm while allowing age-specific relationships to differ by sex, we aimed to estimate the probability that an OHCA in this cohort was initially shockable and to characterise how this probability varied according to age and sex.

Methods

Study population

OHCA cases were identified from the NSW Ambulance OHCA Clinical Quality Registry for the period January 2017 through March 2022. Clinical trial number: not applicable.

EMS System

The state of NSW covers an area of approximately 800,000 km^2 with a population of 8.2 million, served by a single government funded EMS (NSW Ambulance). NSW Ambulance has approximately 6,000 paramedics and provides tiered response to cardiac arrest. Paramedics are graduate entry and can provide ALS (supraglottic airway, defibrillation. Vascular access (IV/IO) and ALS drugs adrenaline, amiodarone, lidocaine). The highest tier; intensive care paramedics bring additional skillsets and senior clinical leadership. Usually both tires respond to cardiac arrests.

Data definitions

Time of arrest: Triple zero (000) call time; Elapsed time: Time from triple zero (000) call to first paramedic arrival on scene.

Inclusion criteria

Adult patients suffering a non-traumatic cardiac arrest where the collapse was witnessed, and resuscitation was attempted by NSW EMS. Initial rhythm was determined from the monitor defibrillator when first applied to the chest.

Exclusion criteria

Cases were excluded if bystander AED was used, rhythm on arrival of EMS was missing or the person arrested after a paramedic arrived (paramedic witnessed).

Statistical Analysis

Data were analysed using generalised additive models (GAMs). The outcome variable was presenting rhythm, dichotomised as shockable (VF/pVT)) versus non-shockable. Sex was included as a binary categorical variable (female/male). A GAM with binomial distribution and logit link was fitted to model the probability of a shockable rhythm. Factor-by-smooth interactions were used to allow sex-specific non-linear effects of age and elapsed response time, with sex additionally included as a parametric term. Smoothing parameters were estimated automatically within the GAM framework. Predicted probabilities and 95% confidence intervals were derived from the fitted model. Model adequacy was assessed using standard GAM diagnostic procedures, including residual analyses, evaluation of concurvity and assessment of spline complexity. Continuous variables were summarised using medians and interquartile ranges, and categorical variables using frequencies and percentages.

Ethics Approval

Ethics approval

to conduct this study was provided by the NSW Population and Health Services Research Ethics Committee (2019/ETH00229) in accordance with the National Statement on Ethical Conduct in Human Research (Australia).

Results

NSW Ambulance attended 45,607 during the period January 2017 through March 2022 of which 5,277 met eligibility criteria. Among the 5,277 patients included in the cohort, 1,653 (31%) were female (Table 1). The overall median age was 70 years (IQR 58–80), with females being older than males (72 years [IQR 59–82] vs 68 years [IQR 57–79]). Arresting shockable rhythm by and sex is depicted in Table 2. Non-shockable rhythms were more common overall (63%) and occurred more frequently among females than males (77% vs 57%), whereas shockable rhythms were more common among males (43% vs 24%). Patients presenting with non-shockable rhythms were older than those with shockable rhythms (72 years [IQR 61–82] vs 65 years [IQR 54–75]). Most cardiac arrests occurred at home (76%), particularly among females (80% vs 74%) and among patients presenting with non-shockable rhythms (80% vs 69%) (Table 1). Median emergency response times were similar between groups, although slightly longer among patients presenting with non-shockable rhythms (9 minutes [IQR 6–12] vs 8 minutes [IQR 6–10]).

Table 1. Participant characteristics

	Male (N=3624)	Female (N=1653)	Overall (N=5277)
Age (years)			
Median [Q1, Q3]	68.0 [57.0, 79.0]	72.0 [59.0, 82.0]	70.0 [58.0, 80.0]
Presenting rhythm			
Non-shockable	2055 (56.7%)	1264 (76.5%)	3319 (62.9%)
Shockable	1569 (43.3%)	389 (23.5%)	1958 (37.1%)
Location of arrest			
At home	2684 (74.1%)	1325 (80.2%)	4009 (76.0%)
Not at home	940 (25.9%)	328 (19.8%)	1268 (24.0%)
Response time (min)			
Median [Q1, Q3]	8.00 [6.00, 11.0]	9.00 [6.00, 11.0]	8.00 [6.00, 11.0]
Bystander CPR			
No	718 (19.8%)	372 (22.5%)	1090 (20.7%)
Yes	2906 (80.2%)	1281 (77.5%)	4187 (79.3%)

Table 2
Arresting shockable rhythm by age and sex

Age (years)	Estimated arresting shockable rhythm at time of collapse (%)			
	Male	**(95%CI)**	**Female**	**(95%CI)**
20	56.80	(42.3–70.2)	70.00	(56.0–81.0)
25	62.00	(51.6–71.4)	67.20	(53.3–78.7)
30	66.40	(58.5–73.5)	64.40	(50.6–76.2)
35	69.70	(63.2–75.4)	61.50	(47.8–73.6)
40	72.00	(66.4–76.9)	58.50	(45.0–70.8)
45	73.50	(68.6–77.9)	55.40	(42.2–67.9)
50	74.10	(69.6–78.1)	52.20	(39.3–64.9)
55	73.40	(69.1–77.3)	49.10	(36.5–61.8)
60	71.20	(66.9–75.1)	46.00	(33.8–58.7)
65	67.60	(63.2–71.7)	42.90	(31.1–55.5)
70	62.90	(58.3–67.3)	39.80	(28.5–52.4)
75	57.40	(52.7–62.0)	36.80	(25.9–49.3)
80	51.20	(46.3–56.0)	34.00	(23.5–46.2)
85	45.00	(39.9–50.2)	31.20	(21.2–43.3)
90	39.80	(33.7–46.1)	28.60	(19.0–40.4)

Bold indicates estimated peak probability of shockable arresting rhythm

The GAM identified significant sex-specific relationships between age, elapsed time and the probability of a shockable rhythm (Fig. 1). The relationship between age and shockable rhythm was non-linear in males (edf 4.14, $\chi^2 = 167.2$, $p < 0.001$), whereas the relationship was approximately linear in females (edf 1.00, $\chi^2 = 51.8$, $p < 0.001$) (Fig. 2). Elapsed time was significantly associated with shockable rhythm in both males (edf 1.00, $\chi^2 = 89.3$, $p < 0.001$) and females (edf 1.88, $\chi^2 = 23.9$, $p < 0.001$), with greater evidence of non-linearity among females (Fig. 2).

At the estimated time of collapse (t = 0), the GAM estimated a probability of a shockable rhythm of 41% (95% CI 27–55%) among females, representing a 17-percentage-point increase compared with the observed presenting shockable rhythm rate of 24% (Fig. 1). Among males, the corresponding estimated probability was 61% (95% CI 56–67%), representing an 18-percentage-point increase compared with the observed presenting rate of 43% (Fig. 1).

Discussion

To the best of our knowledge, this study is the first to use generalised additive modelling to estimate the probability of a shockable rhythm at the time of cardiac arrest from rhythms documented after EMS arrival. In OHCA, the rhythm recorded by EMS may differ substantially from the rhythm present at collapse because of the interval between arrest and professional assessment, during which an initially shockable rhythm may deteriorate to a non-shockable rhythm. By modelling the relationship between elapsed time and documented rhythm, our analysis provides an estimate of the probability of an initial shockable rhythm within the study cohort, rather than relying on the presenting rhythm as a proxy for the rhythm at collapse.

Although VF/pVT accounts for fewer than 50% of presenting rhythms in most OHCA cohorts, studies examining cardiac rhythm at or immediately following the onset of sudden cardiac death have generally reported higher rates. Consistent with these observations, our model-estimated probability of VF/VT at the estimated time of collapse was substantially higher than the observed probability at EMS assessment. Among males, the estimated probability of VF/VT at collapse was 61%, compared with 43% at EMS assessment, while among females it was 41%, compared with 24%, respectively. These findings suggest that reliance on the rhythm documented at EMS assessment may substantially underestimate the proportion of OHCAs that initially present with VF/pVT. Importantly, however, these estimates represent population-level model-based probabilities rather than direct observations of individual patients' initial rhythms.

We observed a non-linear relationship between age and estimated initial VF/pVT probability among males, consistent with findings from a recent Danish study by Casarini et al. (22). In males, the estimated probability of VF/pVT increased through early and middle adulthood, reaching a peak at approximately 50 years of age, before declining with advancing age. In contrast, females demonstrated a more progressive decline in the estimated probability of VF/pVT across the age range, differing from the pattern reported by Casarini et al. (22). The sex-specific patterns observed in our study are nevertheless similar to those reported by Safdar et al. (23), who identified a non-linear relationship between age and survival following OHCA in males but a more consistent decline in survival among females with advancing age. Although survival and initial rhythm are distinct outcomes, the similarity in age- and sex-specific patterns is notable, as the presence of a shockable rhythm is strongly associated with survival following OHCA. This relationship may partly explain the comparable patterns observed between initial rhythm in our study and survival in previous research.

An important finding of our study was that the sex difference in estimated initial VF/pVT probability varied across the lifespan. Women are generally less likely than men to present to EMS with a shockable rhythm; however, our findings suggest that this difference may not be consistent across all ages. At the estimated time of collapse, males aged 18–26 years had a lower estimated probability of VF/VT than females of the same age. From approximately 26 years onwards, this relationship reversed, with males having a higher estimated probability of an initially shockable rhythm than females. Although the

magnitude of the difference diminished with advancing age, females continued to have a lower estimated probability of VF/pVT than males across the remainder of the age range. This age-dependent pattern is again broadly consistent with the survival patterns reported by Safdar et al. (23), although the mechanisms underlying these similarities remain uncertain.

Several mechanisms may contribute to the observed sex differences in VF/pVT. Women with OHCA have been reported to have higher rates of antipsychotic medication use and lower rates of ischaemic heart disease (IHD) than men (10,24,25). Both factors may influence the likelihood of a shockable rhythm: IHD is strongly associated with VF/pVT, whereas antipsychotic medications have been associated with non-shockable rhythms (10). COPD, which has also been reported to be more prevalent among women in some OHCA cohorts (25), is associated with a greater likelihood of non-shockable arrest presentations (10,26). Hormonal and electrophysiological differences may provide additional explanations, including potential effects of oestrogen on ventricular repolarisation and arrhythmia susceptibility, although the mechanisms underlying sex differences in arrest rhythm remain incompletely understood (22).

The non-linear relationship between age and VF/pVT observed in men may similarly reflect changes in the underlying causes and electrophysiological substrate of cardiac arrest across the lifespan (22). The relatively low probability of VF/pVT among younger men may reflect a different distribution of arrest aetiologies compared with middle-aged adults. Younger men have lower rates of IHD and may have a greater contribution from non-ischaemic and non-cardiac causes of arrest, including toxicological exposures, respiratory failure and inherited cardiac conditions. Some of these causes may be less likely to result in a sustained shockable rhythm. Conversely, the increasing probability of VF/pVT through middle age coincides with the increasing prevalence of IHD (27), potentially contributing to the emergence of a more prominent VF/pVT phenotype during this period of life.

The subsequent decline in VF/pVT with advancing age may reflect the increasing contribution of competing mechanisms of cardiac arrest. Advanced heart failure, respiratory disease and multimorbidity become more prevalent with age and are more commonly associated with pulseless electrical activity or asystole than VF/pVT. Age-related myocardial fibrosis and conduction system disease may further alter the electrophysiological substrate, potentially reducing the likelihood of sustained ventricular tachyarrhythmia. Together, these mechanisms could contribute to the observed peak in VF/pVT probability during middle age and its subsequent decline. However, these explanations remain hypotheses, as the present study was not designed to determine the underlying causes of the observed age- and sex-specific patterns.

There is renewed global interest in strategies to improve outcome in OHCA - which largely hasn’t improved in the last 20 years. Many of those strategies are aimed specifically at early recognition of cardiac arrest, early defibrillation and bystander CPR. There is also increasing interest in ECMO CPR (ECPR) strategies for refractory cardiac arrest. Usually, restrictive criteria are used to maximise beneficial outcome and include criteria such as witnessed shockable arrest, early bystander CPR, in patients under 65. This is being examined in both the prehospital and in-hospital arena for OHCA. Our

study may help inform those strategies in that the true VF/pVT arrest incidence is likely under appreciated and ECPR strategies should model around true incidence as improvements are made in case identification and recognition of cardiac arrest and bystander CPR rates.

Technology is increasingly playing a role in cardiac arrest recognition and management. It is likely the wearable technology development (e.g. smart watches) will more accurately determine VF/pVT arrest and potentially auto-activate bystanders via smartphone applications (e.g. GoodSAM), EMS itself and indeed even defibrillator delivery (drone). AI and machine learning will also likely supersede human recognition of cardiac arrest, whilst maintaining acceptable sensitivity. As these processes develop, we would then envisage VF/pVT as presenting rhythm will increase in line with our analysis.

Several considerations are important when interpreting these findings. First, the initial cardiac rhythm was not directly observed in this cohort; rather, it was estimated from the relationship between elapsed time and rhythms documented after EMS arrival. The accuracy of these estimates therefore depends on the validity of this relationship and on the closeness of the triple zero (000) call to the time of collapse and the time of EMS arrival to the time EMS rhythm assessments were recorded. Second, observations close to response time zero were sparse. However, a sensitivity analysis excluding observations within the first 4 minutes produced similar estimates at time zero (see Supplementary Data), suggesting that the results were not substantially driven by the limited number of observations available during the first minutes following collapse. Third, the transition from VF/pVT to a non-shockable rhythm may be influenced by factors other than elapsed time, including bystander CPR effectiveness, resuscitation interventions and underlying patient characteristics. Although the flexible modelling approach allows for non-linear relationships, residual differences between patients may remain unaccounted for. This is consistent with the aim of the analysis, which was to characterise population-level variation in the probability of shockable rhythm rather than to develop an individual-level clinical prediction tool. Fourth, the estimated probabilities describe patterns within the study population and should not necessarily be interpreted as the true probability of an initially shockable rhythm for an individual patient. Further validation in independent OHCA cohorts would be valuable to determine whether the observed age- and sex-specific patterns are reproducible.

Overall, our findings suggest that the proportion of OHCAs that initially present with VF/pVT may be considerably higher than indicated by rhythms documented after EMS arrival. More importantly, the probability of an initially shockable rhythm appears to vary non-linearly with age and differently by sex, including a reversal of the sex difference during early adulthood. These findings highlight the potential limitations of using EMS-presenting rhythm as a direct proxy for initial rhythm and suggest that age and sex may be important considerations when interpreting the epidemiology of shockable rhythms in OHCA.

The overall lower predicted rates of shockable rhythms in women versus men in our study and over time should be evaluated in other jurisdictions. Future prospective research should focus on that gender difference.

Conclusion

Model-based estimates suggest that the proportion of arrests initially presenting with VF/pVT may be substantially higher than the proportion observed at first EMS rhythm analysis. Overall, this study provides evidence that presenting rhythm in OHCA is a dynamic, time-dependent phenomenon and demonstrates the potential value of GAM-based modelling for estimating the probability of a shockable rhythm at or near the time of collapse. These findings provide a more nuanced framework for understanding age and sex differences in OHCA and highlight the importance of considering the timing of rhythm assessment when interpreting epidemiological differences in shockable rhythm.

Declarations

Ethics approval and consent to participate

Ethics approval to conduct this study was provided by the NSW Population and Health Services Research Ethics Committee (2019/ETH00229), according to the National Statement on Ethical Conduct in Research. Human Ethics and Consent to Participate declarations: not applicable

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

This study was conceptualised by BB and SW. Methods by BB and SW. Statistical analysis by SW. All authors contributed to the writing and iterative development of the final manuscript.

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Data Availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

References

1. Yan S G, Y J, N, et al. The global survival rate among adult out-of-hospital cardiac arrest patients who received cardiopulmonary resuscitation: a systematic review and meta-analysis. Crit Care. 2020;24(1):61.
2. Myat, A. Song KJ, Rea T. Out-of-hospital cardiac arrest: current concepts. Lancet. 2018;391(10124):970–9.
3. Benjamin EJMP M, P A, A, American Heart Association Council on Epidemiology and Prevention Statistics Committee and Stroke Statistics Subcommittee, et al. Heart disease and stroke statistics —2019 update: a report from the American Heart Association. Circulation. 2019;139(10):e56–528.
4. Sasson C, Rogers MA, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. *Circ Cardiovasc Qual Outcomes*. 2010;3(1):63–81. Epub 2009 Nov 10. PMID: 20123673.
5. Mader TJ, Nathanson BH, Millay S, Coute RA, Clapp M, McNally B. Out-of-hospital cardiac arrest outcomes stratified by rhythm analysis. Resuscitation. 2012;83(11):1358–62.
6. Cobb LA, Fahrenbruch CE, Olsufka M, Copass MK. Changing incidence of out-of-hospital ventricular fibrillation, 1980–2000. JAMA. 2002;288(23):3008–13.
7. Herlitz J, Svensson L, Engdahl J, Silfverstolpe J. Characteristics and outcome in out-of-hospital cardiac arrest when patients are found in a non-shockable rhythm. Resuscitation. 2008;76:31–6.
8. Majewski D B, S B, P B, J F, J. Long-term survival among OHCA patients who survive to 30 days: Does initial arrest rhythm remain a prognostic determinant? Resuscitation. 2021;162:128–34.
9. Lin YN, Chang SS, Wang LM, Chi HT, Ueng KC, Tsai CF, Phan CS, Lu LH, Hii CH, Chung YT, Chugh SS, Chen MF, Wu TJ, Chang KC. Prehospital Predictors of Initial Shockable Rhythm in Out-of-Hospital Cardiac Arrest: Findings From the Taichung Sudden Unexpected Death Registry (THUNDER). *Mayo Clin Proc*. 2017;92(3):347–359. PMID: 28259227.
10. Granfeldt A, Wissenberg M, Hansen SM, Lippert FK, Lang-Jensen T, Hendriksen OM, Torp-Pedersen C, Christensen EF, Christiansen CF. Clinical predictors of shockable versus non-shockable rhythms in patients with out-of-hospital cardiac arrest. Resuscitation. 2016;108:40–7. Epub 2016 Sep 8. PMID: 27616581.
11. Majewski D, Ball S, Bailey P, Bray J, Finn J. Trends in out-of-hospital cardiac arrest incidence, patient characteristics and survival over 18 years in Perth, Western Australia. Resusc Plus. 2022;9:100201. PMID: 35098176; PMCID: PMC8783140.

12. Jerkeman M, Sultanian P, Lundgren P, Nielsen N, Helleryd E, Dworeck C, Omerovic E, Nordberg P, Rosengren A, Hollenberg J, Claesson A, Aune S, Strömsöe A, Ravn-Fischer A, Friberg H, Herlitz J, Rawshani A. Trends in survival after cardiac arrest: a Swedish nationwide study over 30 years. Eur Heart J. 2022;43(46):4817–29. PMID: 35924401; PMCID: PMC9726448.
13. Oving I, de Graaf C, Karlsson L, Jonsson M, Kramer-Johansen J, Berglund E, Hulleman M, Beesems SG, Koster RW, Olasveengen TM, Ringh M, Claessen A, Lippert F, Hollenberg J, Folke F, Tan HL, Blom MT. Occurrence of shockable rhythm in out-of-hospital cardiac arrest over time: A report from the COSTA group. Resuscitation. 2020;151:67–74. Epub 2020 Apr 8. PMID: 32278017.
14. Waalewijn RA, Nijpels MA, Tijssen JG, Koster RW. Prevention of deterioration of ventricular fibrillation by basic life support during out-of-hospital cardiac arrest. Resuscitation. 2002;54(1):31–6. PMID: 12104106.
15. Bayés de Luna A, Coumel P, Leclercq JF. Ambulatory sudden cardiac death: mechanisms of production of fatal arrhythmia on the basis of data from 157 cases. Am Heart J. 1989;117(1):151–9. PMID: 2911968.
16. Nikolic G, Bishop RL, Singh JB. Sudden death recorded during Holter monitoring. Circulation. 1982;66(1):218–25. PMID: 7083510.
17. Sedgwick ML, Dalziel K, Watson J, Carrington DJ, Cobbe SM. The causative rhythm in out-of-hospital cardiac arrests witnessed by the emergency medical services in the heartstart Scotland project. Resuscitation. 1994;27:55–9.
18. Bougouin W, Mustafic H, Marijon E, Murad MH, Dumas F, Barbouttis A, Jabre P, Beganton F, Empana JP, Celermajer DS, Cariou A, Jouven X. Gender and survival after sudden cardiac arrest: A systematic review and meta-analysis. Resuscitation. 2015;94:55–60. Epub 2015 Jul 2. PMID: 26143159.
19. Cline SL, von Der Lohe E, Newman MM, Groh WJ. Factors associated with poor survival in women experiencing cardiac arrest in a rural setting. *Heart Rhythm*. 2005;2(5):492-6. 10.1016/j.hrthm.2005.01.018. PMID: 15840473.
20. Hasselqvist-Ax I, Riva G, Herlitz J, Rosenqvist M, Hollenberg J, Nordberg P, Ringh M, Jonsson M, Axelsson C, Lindqvist J, Karlsson T, Svensson L. Early cardiopulmonary resuscitation in out-of-hospital cardiac arrest. *N Engl J Med.* 2015;372(24):2307-15. 10.1056/NEJMoa1405796. PMID: 26061835.
21. Amacher SA, Zimmermann T, Gebert P, Grzonka P, Berger S, Lohri M, Tröster V, Arslani K, Merdji H, Gebhard C, Hunziker S, Sutter R, Siegemund M, Gebhard CE, Swiss ICU, Trial Group. Sex disparities in ICU care and outcomes after cardiac arrest: a Swiss nationwide analysis. Crit Care. 2025;29(1):42. 10.1186/s13054-025-05262-5. . PMID: 39849522; PMCID: PMC11756088.
22. Casarini E, Skjelbred T, Rajan D, Warming PE, Hansen CJ, Wolthers SA, Zylyftari N, Torp-Pedersen C, Winkel BG, Christensen HC, Tfelt-Hansen J. Sex differences in out-of-hospital cardiac arrest: the impact of comorbidities on first monitored rhythm. *Resuscitation.* 2025;217:110894. Epub 2025 Nov 11. PMID: 41232591.

23. Safdar B, Stolz U, Stiell IG, Cone DC, Bobrow BJ, deBoehr M, Dreyer J, Maloney J, Spaite DW. Differential survival for men and women from out-of-hospital cardiac arrest varies by age: results from the OPALS study. *Acad Emerg Med*. 2014;21(12):1503-11. PMID: 25491713.
24. Teodorescu C, Reinier K, Uy-Evanado A, Chugh H, Gunson K, Jui J, et al. Antipsychotic drugs are associated with pulseless electrical activity: the Oregon sudden unexpected death study. Heart Rhythm. 2013;10:526–30.
25. Zylyftari N, Wissenberg M, Gnesin F, Møller AL, Anna Mills EH, Møller SG, Jensen B, Ringgren KB, Tan HL, Folke F, Gislason G, Pedersen CT, Lee CJ. Sex differences in out-of-hospital cardiac arrest. Eur Heart J Open. 2025;5(3):oeaf047. PMID: 40395658; PMCID: PMC12089750.
26. Blom MT, Oving I, Berdowski J, van Valkengoed IGM, Bardai A, Tan HL. Women have lower chances than men to be resuscitated and survive out-of-hospital cardiac arrest. Eur Heart J. 2019;40:3824–34.
27. Song J, Yuan K, Huang Y, Chen Z, Wang X, Wang Z, Zhang L. Global, regional, and national burden of ischemic heart disease in young and middle-aged population from 1990 to 2021. Sci Rep. 2025;15(1):41982. PMID: 41290905; PMCID: PMC12647134.

Figures

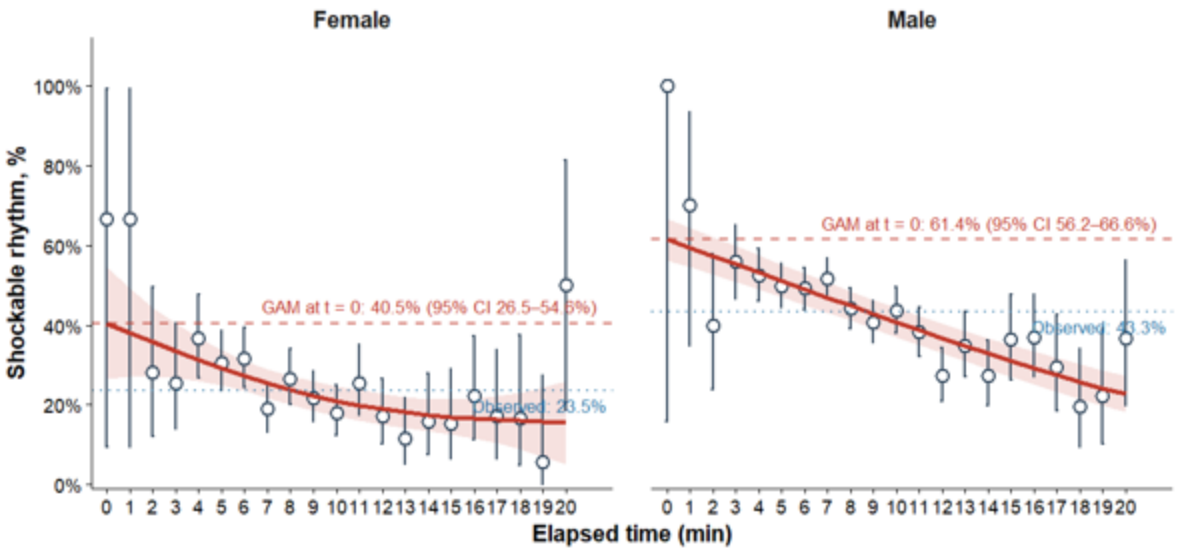


Figure 1

Observed shockable rhythm by time

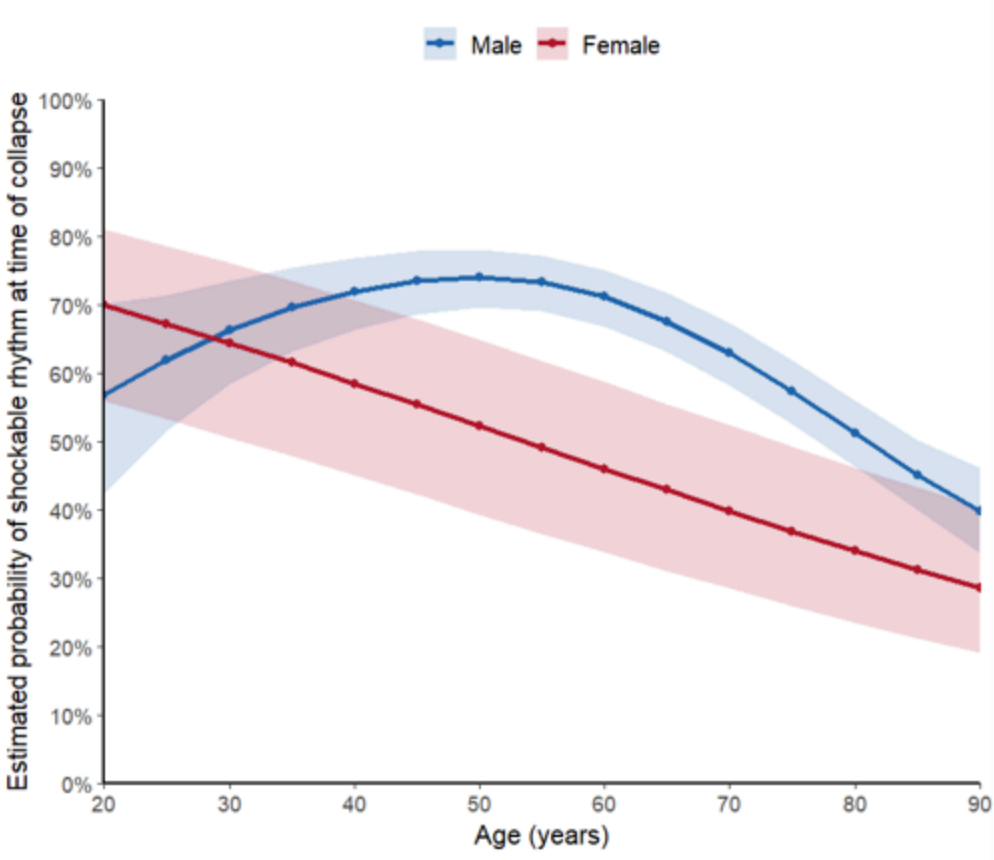


Figure 2

Arresting shockable rhythm by age and sex

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- BeyondthePresentingRhythmSupplementary.docx
- SupplementaryData.docx