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Original research

Defibrillation of persistent shockable rhythms and survival after in-hospital cardiac arrest

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► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/heartjnl-2025-327697).

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Received 12 December 2025
Accepted 17 April 2026

To cite: Sidebottom DB, Jonsson M, Nordkvist EB, *et al*. *Heart* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/heartjnl-2025-327697

ABSTRACT

Background Persistent shockable rhythms (refractory to or recurring after three or more defibrillation attempts) are associated with poorer survival following out-of-hospital cardiac arrest, but little is known about this relationship following in-hospital cardiac arrest (IHCA). This study therefore explored the association between the number of defibrillation attempts and 30-day survival following IHCA.

Method This was a national retrospective cohort study using prospectively collected data from the Swedish Registry for Cardiopulmonary Resuscitation. All cases of adult IHCA between 1 January 2010 and 31 December 2020 presenting with a shockable rhythm who received at least one defibrillation attempt were included. Comorbidity data originated from the Swedish National Patient Register. The exposure was the total number of defibrillation attempts and the primary outcome was 30-day survival. A descriptive analysis was performed, followed by multivariable logistic regression with adjustment for patient and cardiac arrest factors. Missing data were imputed.

Results In total, 5325 IHCA cases were included. Persistent shockable rhythms occurred in 907 (17%) cases. 30-day survival decreased rapidly from 73% in patients receiving one defibrillation attempt to 41% in patients requiring four defibrillation attempts but subsequently plateaued with a minimum value (24%) at nine defibrillation attempts. An unwitnessed arrest (adjusted OR (aOR) 0.50, 95% CI 0.39 to 0.64), the absence of continuous cardiac monitoring (aOR 0.63, 95% CI 0.54 to 0.74) and a longer time to the first defibrillation attempt (aOR 0.89, 95% CI 0.86 to 0.91 per min) were potentially modifiable in-hospital factors associated with decreased survival.

Conclusions A persistent shockable rhythm occurred in around one sixth of IHCAs with an initial shockable rhythm. Successive defibrillation attempts were associated with a rapid fall in survival followed by a plateau phase. These findings warrant further investigation, as patients with IHCA may also benefit from novel strategies to more rapidly terminate shockable rhythms.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Repeated unsuccessful attempts to defibrillate shockable rhythms are associated with poorer survival following out-of-hospital cardiac arrest, but little is known about this relationship following in-hospital cardiac arrest (IHCA).

WHAT THIS STUDY ADDS

⇒ This national Swedish study is the first to report on the association between repeated defibrillation attempts and survival following IHCA.
⇒ Survival to 30 days deteriorated with an increasing number of unsuccessful defibrillation attempts during the initial phase of resuscitation but then reached a plateau phase.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Patients with IHCA may also stand to benefit from novel treatment strategies to more rapidly terminate persistent shockable rhythms.
⇒ This patient group should be considered when designing future interventional research.

INTRODUCTION

The shockable rhythms, ventricular fibrillation (VF) and pulseless ventricular tachycardia (pVT), are most strongly associated with survival after cardiac arrest.[1] However, VF/pVT is resistant to conventional defibrillation strategies in approximately 40% of out-of-hospital cardiac arrest (OHCA) cases.[2–4] After three unsuccessful defibrillation attempts, VF/pVT is typically described as 'refractory', whereas rhythms that are terminated by defibrillation but quickly recur are termed 'recurrent'.[2 5] Because this distinction is rarely made in current clinical practice, the term 'persistent' has been proposed to encompass both patterns.[6]

In OHCA, persistent shockable rhythms are associated with markedly reduced survival and neurological recovery, and active research is underway into novel management strategies, such as vector change and double sequential defibrillation (DSD).[4 7–9] In contrast, relatively little is known about the epidemiology and impact of persistent VF/pVT following in-hospital cardiac arrest (IHCA), and it is unclear whether patients with IHCA may also benefit from these approaches. There are several important differences between the in-hospital and prehospital settings, such as the availability of continuous cardiac monitoring and rapid access to advanced life support.

Understanding the epidemiology and outcomes of persistent shockable rhythms following IHCA is therefore essential to inform future research and guideline development. This study aimed to investigate the association of repeated defibrillation attempts with survival following IHCA and to describe the broader problem of persistent shockable rhythms in this population.

METHOD

Study design

This Swedish national retrospective registry-based cohort study examined the association between the total number of defibrillation attempts and 30-day survival in patients following IHCA. Ethical approval was granted by the Swedish Ethical Review Authority (Dnr 2024–06182-02).

The primary objective was to identify the association between the total number of defibrillation attempts (exposure) and 30-day survival (outcome) after adjustment for important confounders. Secondary objectives included a descriptive analysis of how patient characteristics, arrest-related factors and outcomes vary with the number of shocks administered. The operationalised definition of a persistent shockable rhythm was more than three defibrillation attempts.

Study setting

Data were drawn from two Swedish prospective national registries, crosslinked via the patients' unique national ID.

The Swedish Registry of Cardiopulmonary Resuscitation (SRCR) has collected data on all IHCA cases in Sweden since 2005 and has previously been both described in detail and validated.[10] The SRCR covers all Swedish hospitals with a cardiac arrest team. The definition of IHCA includes all cardiac arrests within a hospital building, including the emergency department and outpatient clinics. IHCA cases are reported to the registry by locally designated resuscitation officers.

The Swedish National Patient Register (NPR) contains all diagnoses according to the International Classification of Diseases (ICD-10 Sweden) set in secondary care in Sweden, either when a patient is admitted to hospital (since 1964) or has contact with a specialist outpatient clinic (since 2001). The NPR is thought to have a diagnostic reliability of over 90% and has been extensively described and validated previously.[11]

Patient and public involvement

Patients were not specifically involved in this research, but the SRCR steering committee includes survivors of cardiac arrest.

Participants

All registered cases of IHCA in the SRCR with an initial shockable rhythm (VF/pVT), which occurred between 1 January 2010 and 31 December 2020, where at least one defibrillation attempt was performed, were included. Patients with missing data on 30-day survival or on the number of defibrillation attempts were excluded. Patients were also excluded where it was not possible to crosslink their SRCR record to a valid NPR record. This occurs when an individual does not have a national ID, for example, temporary residents or tourists.

Variables and data collection

Data on important comorbidities common in patients with cardiac arrest were drawn from the NPR according to ICD-10 code. Comorbidities were selected based on their prevalence and clinical relevance to the IHCA population. Comorbidities drawn from the NPR were only considered valid if the date of diagnosis preceded the date of the cardiac arrest by 1 week or more. All other variables were drawn from the SRCR, including sex, age, cardiac arrest circumstances including the presence of a recent or ongoing myocardial infarction (diagnosis within 72 hours of IHCA), cardiac arrest management and outcome (30-day survival and return of spontaneous circulation (ROSC)). The Intensive Care Society consensus statement was used for definitions of levels of care.[12]

Statistical analysis

Categorical data were presented as counts and percentages, while continuous data were presented as medians with an interquartile interval. A descriptive analysis, stratified by the total number of defibrillation attempts, was performed. Differences in the characteristics of IHCA between levels of care were evaluated using Pearson's χ^2 test for categorical data and the Wilcoxon rank sum test for non-normally distributed numerical data.

Multivariable binary logistic regression was performed with 30-day survival as the dependent variable and the total number of defibrillation attempts as the independent variable. The pattern of data was explored, including assessment of correlation between missing variables. Data were assumed to be missing at random and missing data were imputed through multiple imputation by chained equations (30 imputations each with 50 iterations) using the *mice* package in R.[13] Predictive mean matching was used for numerical-type data, while logistic regression was used for categorical variables. The model was fitted on each imputed dataset and thereafter estimates were pooled using Rubin's rules.

Models were adjusted for age, sex, a previous myocardial infarction, ischaemic heart disease, heart failure, a previous ischaemic stroke, chronic obstructive pulmonary disease (COPD), diabetes mellitus, a recent or ongoing myocardial infarction, time from IHCA identification to defibrillation, the presence of continuous cardiac monitoring and witnessed status. Basis splines with three knots (25th, 50th and 75th centile) were used to model continuous variables that exhibited relationships violating the assumption of linearity with the log odds (age and the number of defibrillation attempts). There were no indications of problematic multicollinearity on exploration. All analyses were performed in R V.4.4 and figures were generated using *ggplot2*.[13]

Sensitivity analysis

A landmark-style analysis was performed to report the conditional probability of unadjusted 30-day survival with an increasing number of defibrillation attempts.

Subgroup analysis

Subgroup analyses of 30-day survival with an increasing number of defibrillation attempts were performed by sex and by the presence or absence of continuous cardiac monitoring.

RESULTS

Of 25 905 IHCA cases which occurred during the study period and were registered in the SRCR, 5738 met inclusion criteria and 5325 were analysed descriptively (figure 1). Persistent VF/pVT was present in 907 (17.0%) IHCA cases, while three or fewer defibrillation attempts were administered in the other 4418 (83.0%) IHCA cases. Overall, ROSC was attained in 4621 (87%) patients and 3284 (62%) patients survived to day 30.

An additional 12 cases were excluded from modelling due to an extreme (>30) number of defibrillation attempts, meaning

that 5313 cases were included in the models. The crude relationship between the total number of defibrillation attempts and 30-day survival is illustrated in figure 2, as well as the modelled relationship both before and after multiple imputation of missing data. Variables with missing data were a recent or ongoing myocardial infarction (9.9% missing), time from IHCA identification to defibrillation (10.1%), the presence of continuous cardiac monitoring (0.8%) and witnessed status (1.4%).

Potentially modifiable in-hospital factors associated with poorer 30-day survival included an unwitnessed arrest (adjusted OR (aOR) 0.50, 95% CI 0.39 to 0.64), the absence of continuous cardiac monitoring (aOR 0.63, 95% CI 0.54 to 0.74) and a longer time to the first defibrillation (aOR 0.89, 95% CI 0.86 to 0.91 per min). The full regression output is available in the supplementary material (online supplemental table 1).

Figure 3 presents the results of the adjusted analysis stratified by sex and by the presence of continuous cardiac monitoring. Figure 4 presents the landmark analysis of conditional 30-day survival with an increasing number of defibrillation attempts.

Characteristics of included IHCA cases, stratified by the number of defibrillation attempts, are presented in table 1. Patients were mainly male (70%) with a median age of 72 years. Included IHCA events were generally witnessed (92%) and in an enhanced care setting (57%) with a patient on continuous cardiac monitoring (77%). An ongoing or recent (within 72 hours) myocardial infarction was present in 2284 (48%) cases where data had been reported. Time to first defibrillation was recorded in 90% cases. The median time to first defibrillation was 1 min (IQR 0–3), while 84.6% of patients received a defibrillation attempt within the Swedish national target of 3 min (online supplemental file 1). Compared with patients on enhanced or critical care units (n=3043), patients who had a cardiac arrest on a normal ward (n=1349) were less often on continuous cardiac monitoring (45% vs 97%, p<0.001), were less frequently witnessed (77% vs 98%, p<0.001), had a longer time to first defibrillation (2 min (IQR 2–4) versus 1 min (IQR 0–2), p<0.001) and a lower 30-day survival (45% vs 69%, p<0.001). The difference between patients on enhanced or critical care units and patients in the emergency department was less marked (online supplemental table 2).

Table 2 presents the characteristics of included cases, stratified by whether the rhythm was responsive (≤three defibrillation attempts) or persistent (>three defibrillation attempts).

DISCUSSION

This national Swedish observational study, spanning 11 years of data on IHCA, reports that around one-sixth of patients with an initial shockable rhythm developed persistent VF/pVT.

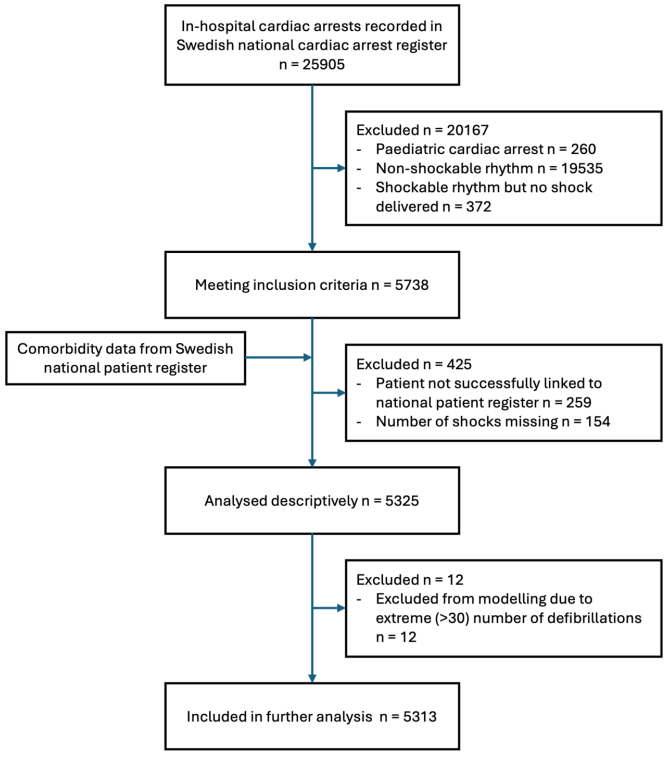

Figure 1 Flow diagram showing inclusion and exclusion of cases.

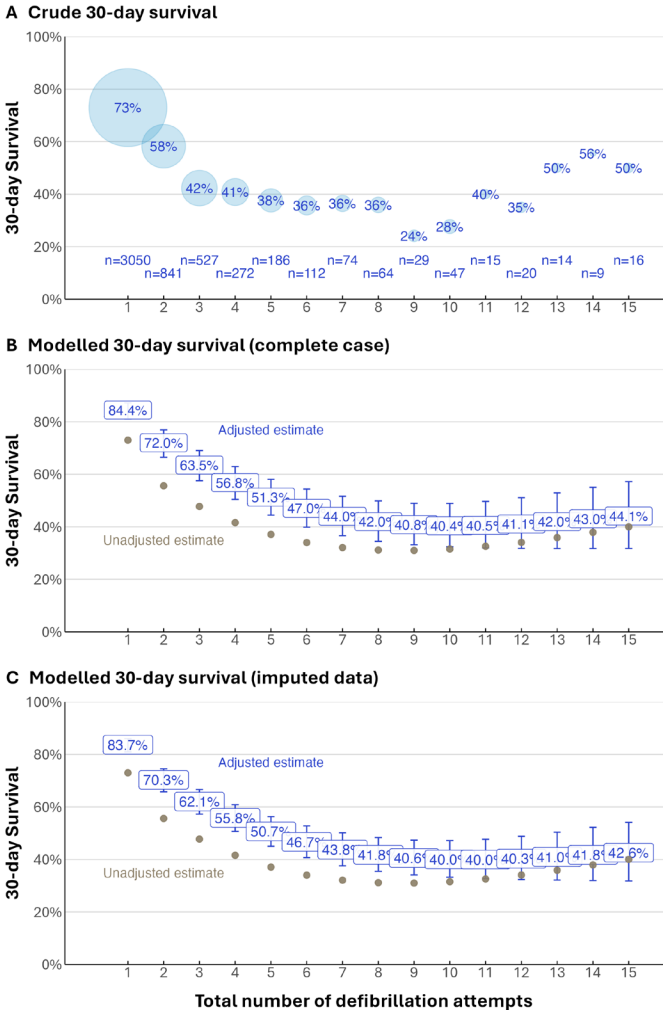

Figure 2 (A) Crude 30-day survival with an increasing number of total defibrillation attempts. Bubble size represents the number of patients, also given underneath as the number of patients (n). (B) Predicted 30-day survival with an increasing total number of defibrillation attempts; univariable and multivariable logistic regression modelling with listwise deletion of missing data. (C) Predicted 30-day survival with an increasing total number of defibrillation attempts; univariable and multivariable logistic regression modelling after multiple imputation of missing data. Multivariable models adjusted for patient age (as basis spline); sex; acute or recent myocardial infarction (within 72 hours); history of myocardial infarction (older than 1 week), ischaemic heart disease, heart failure, stroke, chronic obstructive pulmonary disease and diabetes mellitus; time to first defibrillation attempt; witnessed status of cardiac arrest; presence of continuous cardiac monitoring.

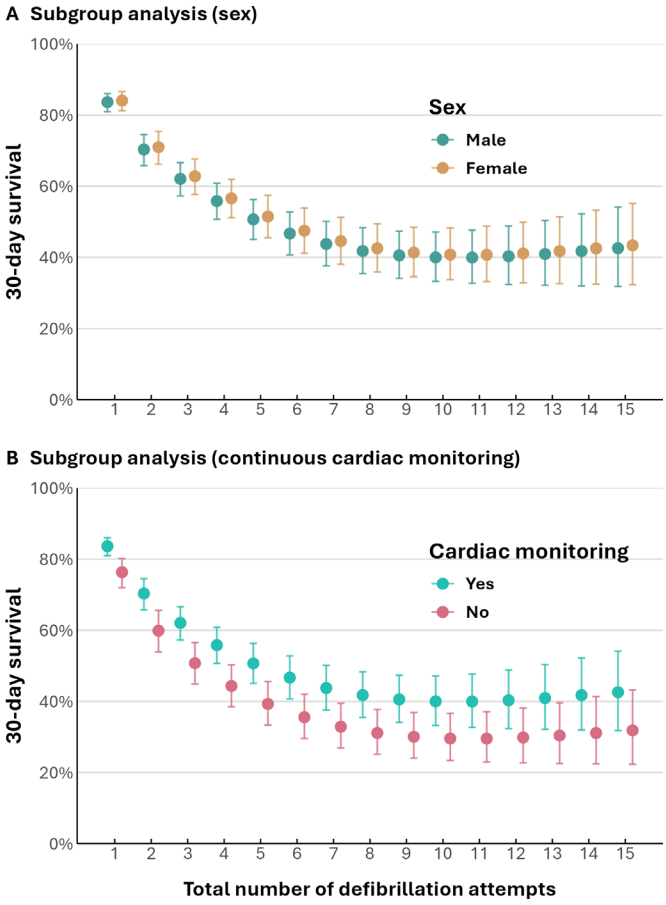

Figure 3 Predicted 30-day survival with an increasing total number of defibrillation attempts. Modelling with multivariable logistic regression, subdivided according to sex (A) and continuous cardiac monitoring (B). Models adjusted for patient age (as basis spline); acute or recent myocardial infarction (within 72 hours); history of myocardial infarction (older than 1 week), ischaemic heart disease, heart failure, stroke, chronic obstructive pulmonary disease and diabetes mellitus; time to first defibrillation attempt; witnessed status of cardiac arrest.

An increasing number of unsuccessful defibrillation attempts were associated with a rapid initial decrease in 30-day survival followed by a plateau after six to eight shocks. IHCA with a shockable presenting rhythm was witnessed in 9/10 of cases, time to first defibrillation was short (1 min), and the overall 30-day survival was around 60%.

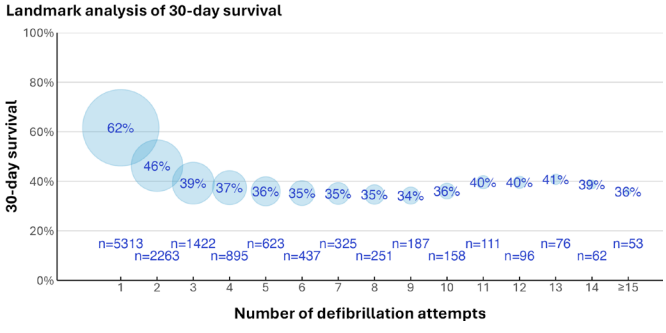

Figure 4 Landmark analysis showing conditional 30-day survival with an increasing number of defibrillation attempts; unadjusted with listwise deletion of missing data. Bubble size represents the number of patients at risk, also given underneath as n.

Number of defibrillation attempts and survival

Crude 30-day survival decreased from 73% in patients who received one defibrillation attempt to 36% in those who received six attempts and thereafter plateaued. This pattern, which was preserved in modelling and in the landmark-style sensitivity analysis, contrasts somewhat with previous analyses of OHCA, where a steeper initial decline in outcomes towards zero has been observed, with no plateau.[4 8 14 15] Nevertheless, the probability of 30-day survival in this study was halved after six defibrillation attempts, suggesting that the rapid termination of VF/pVT is still desirable. Furthermore, comparisons using registry data from Denmark suggest that differences in survival between IHCA and OHCA may be nullified after adjustment for key confounders such as witnessed status.[16]

The total number of defibrillation attempts is entangled with the duration of resuscitation and is subject to survivorship bias. Unsurprisingly, the distribution of the total number of defibrillation attempts was heavily right-skewed, with a very long tail (2% of patients received more than 10 defibrillation attempts). It is likely that some of the extremely protracted resuscitation attempts in this study represented special circumstances, for example, electrical storm and intoxication, and may have included patients with intermittent non-sustained ROSC. This is corroborated by the paradoxical slight upward trend in survival with more prolonged resuscitation attempts.

Studies in other settings have reported conflicting findings with respect to duration of resuscitation and survival from IHCA. One hospital-based cohort study in Sweden previously reported that survival from IHCA with VF/pVT was over 50% even after 15 min of resuscitation,[17] while a large US-based registry study reported that survival to hospital discharge decreased rapidly from 38.4% at the start of resuscitation to 17.9% after 10 min (approximately five shocks).[18] However, the present study did not include patients who had an initial non-shockable rhythm with conversion to a shockable rhythm during the resuscitation attempt. This may explain some of the difference in survival observed in this study when compared with other observational studies of IHCA, as conversion to a shockable rhythm during resuscitation carries a poorer probability of survival than an initial shockable rhythm.[19]

Sex not associated with outcome

In contrast to previous studies in OHCA,[20 21] this analysis found that sex was not a significant predictor in determining survival from IHCA. Miedel *et al* previously showed that over half of the sex-based disparity in survival after OHCA could be attributed to differences in initial rhythm and income.[20] The absence of a sex-based difference in this study is therefore likely explained by the inclusion criteria (only patients with an initial shockable rhythm), the attenuated impact of income in the inpatient setting (the Swedish healthcare system is publicly funded) and, potentially, by exclusion of patients lacking a national identity number.

Comorbidities such as heart failure, COPD, diabetes and stroke were associated with a lower 30-day survival. Beyond a reduction in the physiological reserve of these patients, comorbidities may to some extent reflect differences in socioeconomic status, which is associated with survival from cardiac arrest in the out-of-hospital setting.[21 22]

Time to defibrillation associated with outcome despite short interval

Despite the short and tightly distributed time from identification of cardiac arrest to defibrillation, time to first defibrillation was still associated with survival. This corroborates findings

Table 1 Total number of shocks administered

	Overall	1	2	3	4–5	6–7	8–9	≥10
	n=5325*	n=3050*	n=841*	n=527*	n=458*	n=186*	n=93*	n=170*
Patient factors								
Sex (male)	3750 (70.4%)	2124 (69.6%)	606 (72.1%)	352 (66.8%)	326 (71.2%)	141 (75.8%)	66 (71.0%)	135 (79.4%)
Age (years)	72 (63, 79)	72 (63, 79)	71 (63, 79)	73 (64, 80)	73 (63, 81)	72 (64, 79)	72 (65, 79)	66 (60, 73)
Hypertension (NPR)	2875 (54.0%)	1642 (53.8%)	456 (54.2%)	289 (54.8%)	254 (55.5%)	102 (54.8%)	50 (53.8%)	82 (48.2%)
Atrial fibrillation/flutter (NPR)	1456 (27.3%)	815 (26.7%)	222 (26.4%)	160 (30.4%)	140 (30.6%)	54 (29.0%)	23 (24.7%)	42 (24.7%)
Any diabetes mellitus (NPR)	1350 (25.4%)	747 (24.5%)	219 (26.0%)	136 (25.8%)	133 (29.0%)	37 (19.9%)	31 (33.3%)	47 (27.6%)
Type 1 diabetes mellitus (NPR)	530 (10.0%)	293 (9.6%)	85 (10.1%)	55 (10.4%)	55 (12.0%)	14 (7.5%)	14 (15.1%)	14 (8.2%)
Type 2 diabetes mellitus (NPR)	1295 (24.3%)	706 (23.1%)	213 (25.3%)	134 (25.4%)	130 (28.4%)	37 (19.9%)	29 (31.2%)	46 (27.1%)
COPD (NPR)	523 (9.8%)	290 (9.5%)	92 (10.9%)	62 (11.8%)	51 (11.1%)	13 (7.0%)	8 (8.6%)	7 (4.1%)
Previous stroke (NPR)	515 (9.7%)	291 (9.5%)	75 (8.9%)	62 (11.8%)	51 (11.1%)	12 (6.5%)	8 (8.6%)	16 (9.4%)
Ischaemic heart disease (NPR)	1804 (33.9%)	986 (32.3%)	305 (36.3%)	196 (37.2%)	170 (37.1%)	70 (37.6%)	30 (32.3%)	47 (27.6%)
Heart failure (NPR)	1556 (29.2%)	820 (26.9%)	247 (29.4%)	189 (35.9%)	165 (36.0%)	64 (34.4%)	27 (29.0%)	44 (25.9%)
Previous myocardial infarction (NPR)	1377 (25.9%)	755 (24.8%)	224 (26.6%)	143 (27.1%)	126 (27.5%)	60 (32.3%)	31 (33.3%)	38 (22.4%)
Myocardial infarction <72 hours†	2284 (47.6%)	1277 (45.7%)	376 (49.5%)	230 (50.9%)	183 (45.2%)	95 (59.4%)	43 (53.1%)	80 (55.2%)
Arrest factors								
Cardiac arrest location								
Enhanced care (including OR/IR suite)	3043 (57.1%)	1818 (59.6%)	453 (53.9%)	275 (52.2%)	235 (51.3%)	100 (53.8%)	49 (52.7%)	113 (66.5%)
Emergency department	643 (12.1%)	328 (10.8%)	125 (14.9%)	72 (13.7%)	58 (12.7%)	28 (15.1%)	11 (11.8%)	21 (12.4%)
Ward level care	1349 (25.3%)	747 (24.5%)	216 (25.7%)	155 (29.4%)	132 (28.8%)	45 (24.2%)	26 (28.0%)	28 (16.5%)
Other (radiology, outpatient clinic)	290 (5.4%)	157 (5.1%)	47 (5.6%)	25 (4.7%)	33 (7.2%)	13 (7.0%)	7 (7.5%)	8 (4.7%)
Contact with ICU outreach (within 24 hours)	417 (13.2%)	213 (11.7%)	83 (16.8%)	48 (15.8%)	30 (11.0%)	19 (17.0%)	7 (13.7%)	17 (15.6%)
Continuous cardiac monitoring at time of arrest	4053 (76.7%)	2443 (80.7%)	612 (73.4%)	362 (68.8%)	298 (66.2%)	129 (70.1%)	66 (71.7%)	143 (84.6%)
Witnessed arrest	4816 (91.7%)	2791 (92.9%)	767 (92.5%)	455 (88.2%)	397 (87.3%)	169 (90.9%)	81 (89.0%)	156 (91.8%)
CPR before arrival of cardiac arrest team	3961 (91.4%)	2190 (90.8%)	634 (91.0%)	415 (93.0%)	368 (92.9%)	157 (92.4%)	73 (93.6%)	124 (91.2%)
Intubated during arrest	1659 (32.1%)	508 (17.1%)	301 (37.0%)	265 (52.4%)	269 (60.7%)	125 (67.2%)	59 (65.6%)	132 (78.6%)
Epinephrine administered	2006 (38.9%)	594 (20.2%)	370 (45.7%)	344 (67.5%)	342 (76.2%)	144 (79.1%)	79 (87.8%)	133 (80.1%)
Antiarrhythmic administered	1948 (38.2%)	572 (19.6%)	323 (40.5%)	309 (61.3%)	343 (78.5%)	164 (88.6%)	82 (92.1%)	155 (93.4%)
Outcomes								
ROSC	4621 (87.1%)	2837 (93.1%)	707 (84.6%)	413 (78.7%)	330 (72.5%)	129 (69.4%)	67 (74.4%)	138 (83.6%)
30-day survival	3284 (61.7%)	2226 (73.0%)	490 (58.3%)	223 (42.3%)	181 (39.5%)	67 (36.0%)	30 (32.3%)	67 (39.4%)

*n (%); median (Q1, Q3).
†Diagnosis within 72 hours of cardiac arrest.
COPD, chronic obstructive pulmonary disease; CPR, cardiopulmonary resuscitation; ICU, intensive care unit; IR, interventional radiology; NPR, National Patient Registry; OR, operating room; ROSC, return of spontaneous circulation.

Table 2 Responsive (≤three defibrillation attempts) or persistent (>three defibrillation attempts) shockable rhythm

	All patients n=5313*	Responsive n=4418*	Persistent n=895*
Sex (male)	3740 (70%)	3082 (70%)	658 (74%)
Age (years)	72 (63, 79)	72 (63, 79)	71 (62, 79)
Diabetes mellitus (NPR)	1349 (25%)	1102 (25%)	247 (28%)
COPD (NPR)	523 (9.8%)	444 (10%)	79 (8.8%)
Previous stroke (NPR)	515 (9.7%)	428 (9.7%)	87 (9.7%)
Ischaemic heart disease (NPR)	1802 (34%)	1487 (34%)	315 (35%)
Heart failure (NPR)	1553 (29%)	1256 (28%)	297 (33%)
Previous myocardial infarction (NPR)	1376 (26%)	1122 (25%)	254 (28%)
Myocardial infarction <72 hours†	2280 (48%)	1883 (47%)	397 (51%)
Minutes to first defibrillation	1 (0, 3)	1 (0, 2)	1 (0, 3)
Continuous cardiac monitoring at time of arrest	4041 (77%)	3417 (78%)	624 (71%)
Witnessed arrest	4804 (92%)	4013 (92%)	791 (89%)
ROSC	4609 (87%)	3957 (90%)	652 (74%)
30-day survival	3274 (62%)	2939 (67%)	335 (37%)

*n (%); median (Q1, Q3).
†Diagnosis within 72 hours of cardiac arrest.
COPD, chronic obstructive pulmonary disease; NPR, National Patient Registry; ROSC, return of spontaneous circulation.

from other registry-based studies demonstrating that a delay to defibrillation is associated with a lower probability of defibrillation success,[23] while prompt defibrillation of IHCA (within 2 min) is associated with improved patient outcomes,[24] and perhaps hints at the survival gap in OHCA in Sweden, where time to first defibrillation is around 10 min.[4]

Clinical implications

Although based on observational associations, these findings highlight the rapid fade in survival during the initial phase of resuscitation during IHCA and the importance of terminating VF/pVT as soon as possible. As resuscitation attempts are generally continued while a shockable rhythm persists, termination of resuscitation in this patient group was probably preceded, in most cases, by conversion to a non-shockable rhythm. Therefore, despite the effect of survivorship bias, the probability of survival observed in this study may be relevant to similar populations, provided that the patient is still in a shockable rhythm. The relatively high rate of survival observed after even protracted resuscitation attempts may therefore be of interest to clinicians, although should be interpreted with caution and not taken as evidence of specific benefit or futility thresholds, given the selected population.

Alternative defibrillator pad placement is gaining interest as a strategy to terminate persistent shockable rhythms; vector change defibrillation is recommended in the 2025 update to European Resuscitation Council guidelines, while trials of DSD are ongoing (although inclusion is limited to OHCA).[5 7 9 25] Additional management strategies for persistent VF/pVT can include increased defibrillation energy, primary percutaneous coronary intervention and extracorporeal membrane oxygenation, where available.[25 26] Other emerging strategies, including 'de-emphasised' epinephrine dosing, alternative antiarrhythmic agents such as cardioselective beta blockers and stellate ganglion block, currently lack high-quality evidence.[6 27]

IHCAs with an initial shockable rhythm on general wards were associated with worse prognostic indicators, some of which are modifiable. Pseudo-witnessed status is potentially modifiable in hospitals through timely and appropriate escalation of the level of care, facilitated via rapid response teams and through the development of advanced patient monitoring systems such as ubiquitous continuous vital sign monitoring.[10 25 28] Time to first defibrillation, which affects the probability of successful defibrillation and survival, was significantly longer on normal wards, despite the presence of an automated external defibrillator on hospital wards being standard.[4 8 23] This could in part be addressed through improved training in basic life support with opportunities for regular simulation/refreshment of skills.

Strengths and limitations

These findings are subject to several important limitations. First, only the total number of shocks delivered is reported, while some patients may have experienced recurrent/intermittent ROSC. These cases likely have a different prognosis given the intermittent restoration of a more physiological coronary and cerebral perfusion, but are not distinctly identifiable within the SRCR. Furthermore, the SRCR does not specify a clear definition of ROSC, likely resulting in heterogeneity in how ROSC is classified. Second, a time-to-event analysis would have been preferable given that the number of defibrillation attempts is entangled with the duration of resuscitation; however, this was not possible given the lack of reliable timing data. Potential confounding variables such as cardiopulmonary resuscitation quality, which may affect both rhythm and 30-day survival, were not measured. Third, data are generally collected post-hoc from patient notes, although the direction of any potential reporting bias is unclear. Fourth, underreporting of IHCA cases to the SRCR occurs, particularly when patients experience a shockable rhythm in an enhanced care setting and are rapidly and successfully defibrillated.[10] There may also be underreporting of IHCA events where resuscitation is swiftly terminated due to futility, although this is less likely to be the case for patients in VF/pVT. Overall, the direction of misclassification and reporting biases is unclear. Fifth, the tail end of the study period included the COVID-19 pandemic, which was associated with poorer outcomes from cardiac arrest.[29] Last, the SRCR does not collect data on off-guideline management strategies for persistent VF/pVT that are used in clinical practice.[6] Strengths of this study include the comprehensive coverage of the nationwide, previously validated registers utilised, as well as the robust statistical analysis.

CONCLUSIONS

In this national, observational, in-hospital, Swedish study, around one-sixth of patients with an initial shockable rhythm developed persistent VF/pVT. Survival to 30 days decreased during the initial phase of resuscitation with an increasing number of unsuccessful defibrillation attempts but then plateaued. Patients with IHCA may stand to benefit from novel treatment strategies to more rapidly terminate VF/pVT.

Contributors DBS: methodology, formal analysis, visualisation, writing – original draft preparation and writing—review and editing; MJ: methodology, formal analysis, visualisation and writing—review and editing; EBN: writing—review and editing; LH: writing—review and editing; CM: writing—review and editing; AC: writing—review and editing; GF: writing—review and editing; AA: conceptualisation, writing—review and editing and supervision; GR: conceptualisation, methodology, writing—review and editing, project administration, supervision, guarantor.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design or conduct or reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by Ethical approval was granted by the Swedish Ethical Review Authority on 1 November 2024 (Dnr 2024-06182-02). This was a registry-based study using previously collected data. Since 2013, survivors of cardiac arrest have been sent a letter approximately 6 months after the event with information about their inclusion in the register. Survivors can request to have their data erased from the register, but this is very uncommon.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Selected data are available upon reasonable request to the corresponding author.

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REFERENCES

1 McBride O, Poel A, Counts CR, *et al*. Temporal Patterns in Out-of-Hospital Cardiac Arrest Incidence and Outcome. *JAMA Cardiol* 2025;10:922–31.
2 Nas J, Thannhauser J, Bonnes JL, *et al*. Importance of the distinction between recurrent and shock-resistant ventricular fibrillation: Call for a uniform definition of refractory VF. *Resuscitation* 2019;138:312–3.
3 Alhenaki A, Alqudah Z, Williams B, *et al*. Temporal trends in the incidence and outcomes of shock-refractory ventricular fibrillation out-of-hospital cardiac arrest. *Resusc Plus* 2024;18:100597.
4 Harrysson L, Blick E, Awad A, *et al*. Survival in relation to number of defibrillation attempts in out-of-hospital cardiac arrest. *Resuscitation* 2024;205:S0300-9572(24)00810-4.
5 Cheskes S, Drennan IR, Turner L, *et al*. The impact of alternate defibrillation strategies on shock-refractory and recurrent ventricular fibrillation: A secondary analysis of the DOSE VF cluster randomized controlled trial. *Resuscitation* 2024;198:S0300-9572(24)00079-0.
6 Sidebottom DB, Gleeson-Hammerton T, Pike J, *et al*. Management of persistent shockable rhythms during cardiac arrest: a national survey from the REVIVE group (REVIVE-2). *Resusc Plus* 2025;25:101008.
7 Cheskes S, Verbeek PR, Drennan IR, *et al*. Defibrillation Strategies for Refractory Ventricular Fibrillation. *N Engl J Med* 2022;387:1947–56.
8 Holmén J, Hollenberg J, Claesson A, *et al*. Survival in ventricular fibrillation with emphasis on the number of defibrillations in relation to other factors at resuscitation. *Resuscitation* 2017;113:33–8.
9 Blick Nordkvist E, Awad A, Riva G, *et al*. Early double sequential defibrillation - a randomized pilot study. *Eur Heart J* 2025;46.
10 Silverplats J, Äng B, Källestedt M-LS, *et al*. Incidence and case ascertainment of treated in-hospital cardiac arrest events in a national quality registry - A comparison of reported and non-reported events. *Resuscitation* 2024;195:S0300-9572(24)00012-1.
11 Ludvigsson JF, Andersson E, Ekbom A, *et al*. External review and validation of the Swedish national inpatient register. *BMC Public Health* 2011;11:450.
12 Intensive Care Society. Levels of adult critical care second edition: consensus statement. London; 2021.
13 R Core Team. R: a language and environment for statistical computing.
14 Hasegawa M, Abe T, Nagata T, *et al*. The number of prehospital defibrillation shocks and 1-month survival in patients with out-of-hospital cardiac arrest. *Scand J Trauma Resusc Emerg Med* 2015;23:34.
15 Awad E, Klapthor B, Morgan MH, *et al*. The impact of time to defibrillation on return of spontaneous circulation in out-of-hospital cardiac arrest patients with recurrent shockable rhythms. *Resuscitation* 2024;201:S0300-9572(24)00180-1.
16 Høybye M, Stankovic N, Holmberg M, *et al*. In-Hospital vs. Out-of-Hospital Cardiac Arrest: Patient Characteristics and Survival. *Resuscitation* 2021;158:157–65.
17 Rohlin O, Taeri T, Netzereab S, *et al*. Duration of CPR and impact on 30-day survival after ROSC for in-hospital cardiac arrest-A Swedish cohort study. *Resuscitation* 2018;132:1–5.
18 Okubo M, Komukai S, Andersen LW, *et al*. Duration of cardiopulmonary resuscitation and outcomes for adults with in-hospital cardiac arrest: retrospective cohort study. *BMJ* 2024;384:e076019.
19 Cournoyer A, Cossette S, Potter BJ, *et al*. Prognostic impact of the conversion to a shockable rhythm from a non-shockable rhythm for patients suffering from out-of-hospital cardiac arrest. *Resuscitation* 2019;140:43–9.
20 Miedel C, Jonsson M, Rawshani A, *et al*. Exploring underlying reasons for the difference in sex-specific survival following out-of-hospital cardiac arrest - a mediation analysis. *Eur Heart J* 2023;44.
21 Smits RLA, Tan HL, van Valkengoed IGM. Sex Differences in Out-of-Hospital Cardiac Arrest Survival Trends. *J Am Heart Assoc* 2024;13:e032179.
22 Jonsson M, Härkönen J, Ljungman P, *et al*. Inequalities in Income and Education Are Associated With Survival Differences After Out-of-Hospital Cardiac Arrest: Nationwide Observational Study. *Circulation* 2021;144:1915–25.
23 Stieglis R, Verkaik BJ, Tan HL, *et al*. Association Between Delay to First Shock and Successful First-Shock Ventricular Fibrillation Termination in Patients With Witnessed Out-of-Hospital Cardiac Arrest. *Circulation* 2025;151:235–44.
24 Chan PS, Krumholz HM, Nichol G, *et al*. Delayed time to defibrillation after in-hospital cardiac arrest. *N Engl J Med* 2008;358:9–17.
25 Soar J, Böttiger BW, Carli P, *et al*. European Resuscitation Council Guidelines 2025 Adult Advanced Life Support. *Resuscitation* 2025;215 Suppl 1:S0300-9572(25)00281-3.
26 Pocock H, Deakin CD, Lall R, *et al*. Prehospital optimal shock energy for defibrillation (POSED): A cluster randomised controlled feasibility trial. *Resusc Plus* 2024;17:100569.
27 Holmberg MJ, Granfeldt A, Mentzelopoulos SD, *et al*. Corrigendum to "Vasopressin and glucocorticoids for in-hospital cardiac arrest: A systematic review and meta-analysis of individual participant data" [Resuscitation 171 (2022) 48–56]. *Resuscitation* 2023;190:109929.
28 Rowland BA, Motamedi V, Michard F, *et al*. Impact of continuous and wireless monitoring of vital signs on clinical outcomes: a propensity-matched observational study of surgical ward patients. *Br J Anaesth* 2024;132:519–27.
29 Sultanian P, Lundgren P, Strömsöe A, *et al*. Cardiac arrest in COVID-19: characteristics and outcomes of in- and out-of-hospital cardiac arrest. A report from the Swedish Registry for Cardiopulmonary Resuscitation. *Eur Heart J* 2021;42:1094–106.