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Temporal variation in survival following in-hospital cardiac arrest in Sweden

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ABSTRACT

Background: The aim of the study was to investigate what characterizes IHCAs that take place during the "day" (Monday-Friday 7 am-3 pm), "evening" (Monday-Friday 3 pm–9 pm) and "night" (Monday-Friday 9 pm-7 am and Saturday-Sunday 12 am- 11.59 pm).

Methods: We used the Swedish Registry for CPR (SRCR) to study 26,595 patients from January 1, 2008 to December 31, 2019. Adult patients ≥18 years with a IHCA where resuscitation was initiated were included. Uni- and multivariable logistic regression was used to investigate associations between temporal factors and survival to 30 days.

Results: 30-day survival and Return of Spontaneous Circulation (ROSC) was 36.8% and 67.9% following CA during the day and decreased during the evening (32.0% and 66.3%) and night (26.2% and 60.2%) ($p < 0.001$ and $p = 0.028$). When comparing the survival rates between the day and the night, survival decreased more (change in relative survival rates) in small (<99 beds) compared to large (<400) hospitals (35.9% vs 25%), in non-academic vs academic hospitals (33.5% vs 22%) and on non-Electro Cardiogram (ECG)-monitored wards vs ECG-monitored wards (46.2% vs 20.9%) ($p < 0.001$ for all). IHCAs that took place during the day (adjusted Odds Ratio (aOR) 1.47 95% CI 1.35–1.60), in academic hospitals (aOR 1.14 95% CI 1.02–1.27) and in large (>400 beds) hospitals (aOR 1.31 95% CI 1.10–1.55) were independently associated with an increased chance of survival.

Conclusions: Patients suffering an IHCA have an increased chance of survival during the day vs the evening vs night, and the difference in survival is even more pronounced when cared for at smaller, non-academic hospitals, general wards and wards without ECG-monitoring capacity.

1. Background

Outcomes for a number of diseases tend to be worse during the night and weekend compared to the daytime and on week-days. Overall survival following hospital admission on weekends is lower compared to week-day admissions [1], survival following admission due to acute myocardial infarction is worse on week-ends [2] and survival following IHCA (in-hospital cardiac arrest) is decreased during nights and week-

Abbreviations: CA, Cardiac arrest; CPR, Cardiopulmonary resuscitation; IHCA, In-hospital cardiac arrest; ROSC, Return of spontaneous circulation; VF/pVT, Ventricular fibrillation/pulseless ventricular tachycardia; PEA, Pulseless electrical activity; SRC, Swedish Resuscitation Council; CAT, Cardiac arrest team; ICU/CCU, Intensive care unit/coronary care unit; AED, Automated external defibrillator; OR, Odds ratio.

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ends [3]. Understaffing [4], less experienced staff [1], lack of diagnostic [1] and therapeutic capacity [2] are some of the suggested causes for the difference in outcome. Large national register studies from the United States of America (US) [5], United Kingdom (UK) [6] and Sweden [3] have consistently shown increased OR for death following IHCA during "off-hours". Other temporal factors such as time of year and vacation period possibly also affect outcome: an increased risk of death following surgery during the vacation period (the august effect) has been demonstrated for several elective procedures [7]. A deeper understanding of the underlying causes of temporal variation in IHCA outcomes is lacking.

The present study is based on the Swedish Registry for Cardiopulmonary Resuscitation (SRCR). The aim of the study was to investigate what characterizes IHCAs that take place during the "day" (Monday-Friday 7 am-3 m), "evening" (Monday-Friday 3 pm–9 pm) and "night" (Monday-Friday 9 pm-7 am and Saturday-Sunday am-pm).

2. Methods

2.1. Study population and setting

This is a registry-based cohort study of all IHCAs registered in the SRCR from 1 January 2008 to 31 December 2019. The patient population is representative of the Swedish IHCA population since all hospitals in Sweden that are large enough to have emergency care facilities/CATs report to the register. The Swedish health care system is almost free of charge (tax based) and patients are included from all socioeconomic groups. According to statistics Sweden, the Swedish population is diverse with approximately 20% of inhabitants having been borne abroad (ref SCB Utrikes födda i Sverige (scb.se)).

The registry was designed to comply with the Utstein style of reporting IHCA research [8]. The registry is a national quality registry and publishes an annual report presenting nationwide characteristics and trends.

The SRCR contains variables including age, gender, witnessed status, cause of alarm, location of cardiac arrest, electrocardiogram (ECG) monitoring, time to call, time to CPR, time to defibrillation, initial rhythm, treatment characteristics and short-term outcome, as-well as 30-day survival and neurologic function pre-arrest and at discharge (measured by Cerebral Performance Categories, CPC-score). The study complies with the Declaration of Helsinki and was approved by the regional ethical board in Gothenburg, Sweden (reference Nr: 018–18). For review and validation of the SRCR, please refer to Hessulf et al. [9].

2.2. Inclusion and exclusion criteria

The study included all patients aged 18 years and older who suffered an IHCA, between 1 January 2008 and 31 December 2019 and in whom resuscitation was started. Patients with unknown time of IHCA (where time of day/week/month/year of IHCA was missing in the registry) were excluded. For a review of included and excluded patients see supplement 1.

2.3. Statistical analysis

Baseline characteristics are presented using means, medians and proportions, with appropriate measurements of dispersion. Hypothesis testing was performed between the three time groups using Chi-squared test for categorical variables and one-way ANOVA for continuous variables. Standard Mean Difference (SMD) was calculated for baseline characteristics and outcome variables. SMD is the difference between the means for two groups divided by their standard deviation. Values below 0.1 (10%) are considered inconsequential.

The association between time of cardiac arrest and 30-day survival was ultimately evaluated using multivariable logistic regression, with adjustment for covariates of clinical importance or displaying varying distributions between the groups at baseline. Two-sided *P*-values$<$0.05 were considered statistically significant. To evaluate the multivariate logistic regression model, Nagelkerke's R2 was calculated.

We also computed odds ratios (ORs) in the entire population by imputing missing data using Multiple Imputation by Chained Equations (MICE) algorithm [10]. 1 data set were imputed, and a second multivariable logistic regression model was created. We compared the ORs obtained with the original model with those obtained in the complete case set. MICE is a method of dealing with missing data and evaluates if the loss of data is likely to have affected the observed results.

We used R (https://r-project.org) for all analyses.

3. Results

3.1. Baseline characteristics

A total of 26,595 IHCA patients were included in the SRCPR between 1 January 2008 and 31 December 2019, of which 24,794 patients met the study criteria.

There were no or only small differences in basic demographic variables such as age, gender and distribution of co-morbidities between the three time groups. Small but significant differences in the location of CA were observed, CA during the daytime was more frequent in locations that are more often occupied during the day compared to the nigh (Outpatient clinic, cardiac catheterization lab) whereas CAs were more frequent during the night time and week-ends on general wards. CA that occurred during the day and evening were more often witnessed, had a shockable initial rhythm and were more frequently defibrillated within 3 min compared to CA during week-ends or during the night. Small differences in the frequency of CA were observed when comparing hospitals by size and type (academic vs non-academic) across the three time categories. For an illustration of the incidence and 30-day survival by time of day, day of week and month of year, please refer to supplement 2.

3.2. 30-day survival, ROSC and CPC-score

30-day survival and rate of ROSC were highest during daytime (7 am-3 pm) on weekdays (36.8% and 67.9% respectively), decreased in the evening (3 pm–9 pm) on weekdays (32.0% and 66.3%) and decreased even further during the night (9 pm-7 am) and during weekends (am-pm) (26.2%, and 60.2%, p < 0.001 and p = 0.028 respectively). Good neurological outcome (CPC = 1) was more common following CA during the daytime (80.5%) and evening (79.1%) during week-days comparted to nighttime and week-ends (76.6%) (p = 0.028)). For trends in 30-day survival and ROSC 2008–2019, refer to supplement 3.

IHCAs in wards with high minimum staffing showed smaller fluctuations in 30-day survival (Cardiac Care Unit (CCU), Intensive Care Unit (ICU), cardiac catheterization lab) compared to general wards when comparing the difference between mean survival during the daytime (maximum survival) compared to the night/week-end (minimum survival). The largest hospitals (>400 beds) and academic hospitals had smaller differences in mean survival between the daytime and night/week-end compared to smaller hospitals or non-academic hospitals. ECG-monitoring IHCAs exhibited smaller fluctuations in survival over the day-evening-week-end compared to non-ECG-monitored IHCAs.

When comparing the effect of the vacation period (July-Aug) vs the rest of the year on 30-day survival and ROSC stratified by time of day and day of week (week-days 7 am-3 pm vs week-days 3 pm–9 pm vs week-day nights 9 pm-7 am and week-ends 00.01 am-11.59 pm) survival and ROSC was lower during the vacation period. Survival and ROSC decreased from day➔evening➔night irrespective of vacation or not. There were larger variations in ROSC and survival when comparing the day vs the night in the non-vacation period compared to the vacation period.

The largest difference in ROSC and survival between the vacation period and the non-vacation period was seen during the day, only small differences in survival was seen during the evening and night (supplement 3).

The relative frequency of pulseless ventricular tachycardia/ventricular fibrillation (pVT/VF), Pulseless Electromechanical Activity (PEA) and asystole varied over the course of the day/week with relatively larger proportions of pVT/VF occurring during the day compared to the night.

The proportion of witnessed CA was higher during the day and evening compared to the night (84% 85% vs 78%). Delay times <3 min from CA to defibrillation among patients with a shockable rhythm were less common during the evening and night (59% and 57% respectively) compared to during the day (62%).

3.3. Independent predictors of survival

After adjusting for covariates in the multivariate logistic regression model, multiple factors were independently associated with 30-day survival. Most notably, hospital size (>400 beds compared to 0–99, 100–250, 250–400), academic hospital (compared to non-academic) and IHCA during the day-time on week-days (compared to evening and nights) were independently associated with an increased chance of survival. The multivariable logistic model explained approximately 47% of the variance in survival as measured by Nagelkerke's $R2 = 0.4699$.

4. Discussion

Survival, rate of ROSC and good neurological outcome following IHCA was higher during the day and decreased in the evening and night. The observed difference in survival across time groups was accompanied with differences in initial rhythm, witnessed status and time to defibrillation. CA during the day, at large hospitals or academic hospitals was independently associated with an increased chance of survival, and the observed survival difference increased even further from day to evening to night.

4.1. Time of day and downstream effects on CA initial rhythm and immediate treatment

Our results illustrate some of the immediate effects of time of day of CA – the proportion of witnessed CAs decreased from day to night by 7%, an association that's very likely due to less staff during the night. The proportion of patients found with an initial rhythm of pVT/VF decreased by 15%, asystole increased by an equal amount but the proportion of PEA remained largely the same (27% PEA during the day, 27% PEA during the night). An untreated initial rhythm of pVT/VF will with time deteriorate to asystole and its possible that some of the patients found in asystole during the night initially had a shockable rhythm, but due to delayed detection and treatment deteriorated to asystole. The proportion of patients found in a shockable rhythm that were defibrillated within 3 min also decreased (by 8%) from day to night, possibly due to less staff and lower level of expertise during the night. Witnessed status, initial rhythm and time from CA to defibrillation have been shown to influence 30-day survival [3,9] and probably contributed to the decreased chance of survival during the evening and night. Ofoma et al. [11] investigated trends in IHCA survival 2000–2014 and showed increased rates of survival for both IHCA during the day and the night, but the difference in survival rates persisted i.e. it is likely that the factors driving the survival difference persisted. Supplement 3 shows trends in survival and rates of ROSC 2008–2019 and we conclude that similar trends were found in our data: a general increase in survival and rates of ROSC, but no clear indication that the survival gap had narrowed over time.

4.2. Effect of time of day on 30-day survival is modified by hospital and ward characteristics and circumstances at resuscitation

4.2.1. Ward characteristics

When examining the fluctuations in survival in the three time categories (Tables 2-3), wards that traditionally have the smallest variation in nurse-to-patient ratio (NTP-ratio) between the day and the night shift (ie cardiac care unit, cardiac catheterization lab, the intensive care unit) showed smaller differences in survival day➔night compared to general wards (10.8% 10.5%. 20.7% vs 30.4%) ($p < 0.05$ for all). The risks of adverse events and mortality have been shown to increase when the nurse to patient ratio (NPR) is below 1:8 on the general ward [12]; during night shifts NPRs of 1:8–1:23 have been reported [13]. Night shifts consistently have lower nurse to patient ratios: for every one patient increase in nurse work load there is a 7% increase in mortality [12] Interestingly, in the present study the survival rate was slightly higherin the ED during the day-time (34.1%) compared to the night-time (36.6% non-significant p-value($p = 0.488$)), >). A recent study [14] showed that nurse to patient ratio for Swedish ED's is the opposite to general wards: the NPR is at its lowest during the day and evening(00.01 pm–11.59 pm) at ≈ 1:4) and significantly higher (≈ 1:2) during the night and morning (00.01 am–11.59 am) which could explain this somewhat contradictory increase in observed survival during evenings and night. Another possible reason no decrease in survival was observed in the ED from day to night time could be differences in case mix from day to night.

4.2.2. Hospital characteristics

Among all patients, survival decreased from day to evening to night. However, larger hospitals (>400 beds) exhibited smaller changes in survival day vs night (25%) compared to smaller hospitals (250–400 vs 100–249 vs 0–99 beds) (33% ➔ 31.7% ➔ 35.9%), an association that seemed to suggest a degree of linearity ($p < 0.001$ for all). Data from the UK [15] show that the average number of patients in each ward that the doctor cared for during the day-time (11 pm) was 11 (2–65) but rose to 61(1–400) at 11 pm. The same study shows that senior physicians i.e. consultants were only present overnight in 6.1% of cases. UK and Swedish hospitals are staffed in a similar fashion during the night, and this relative increase in physician to patient ratio and decrease in experienced physicians on call during the night probably explain some of the decrease in IHCA survival from day to evening to night. A review of Swedish hospitals [16] shows that at many smaller hospitals, the most senior physicians on call to care for both medical and surgical patients during the night is often an intern with 1–2 years of experience as a physician, and at best a junior resident with 3–4 years of experience. At larger hospitals, there is often one internal medicine resident, one surgery resident, 1–2 interns, one pediatrics resident and one anesthesiology/intensive care resident/fellow. The larger the hospital, the more physicians with more experience on call during the night. It is possible that the smaller decrease in survival,when comparing the day vs night, at the larger hospitals is due to the smaller decrease in physician experience at larger hospitals compared to smaller hospitals. IHCA survival was, in a similar fashion, lower at non-academic hospitals compared to academic hospitals. Academic hospitals tend to be larger and cover more specialties than non-academic hospitals, and it is likely that the smaller decrease in survival at academic hospitals is explained by the same factors as the relatively small decrease in survival at larger hospitals.

4.2.3. Circumstances at resuscitation

Patients that experienced a CA while ECG-monitored showed smaller decreases in survival (relative survival rate difference 20.9% vs 46.2%) when comparing the day vs night compared to non-ECG-monitored patients. The ECG-monitored CA should by definition be detected with similar delay during the day vs the night, our interpretation is that the decrease in survival (20.9%) should therefore be due to other factors such as a less experienced team, longer delay from CA to angiography etc. Indeed, even among witnessed CA the survival rate decreased from

Table 1
Baseline characteristics by time of day and day of week.

	7 am-3 pm weekday	3 pm–9 pm weekday	9 pm-7 am weekday + weekend am-pm	p	SMD	Missing (%)
n	7426	4694	12,674			
Age (mean (SD))	72.49 (13.18)	72.82 (13.13)	72.53 (13.32)	0.360	0.017	0(0)
Sex = female (%)	2856 (38.5)	1758 (37.5)	4918 (38.8)	0.259	0.019	12 (0)
Heart failure (%)	2349 (34.5)	1483 (34.5)	4205 (36.2)	0.023	0.025	507 (1.9)
Diabetes (%)	1864 (26.1)	1217 (26.9)	3399 (27.8)	0.035	0.025	505 (1.9)
Respiratory insuff (%)	1498 (21.3)	974 (21.9)	2975 (24.8)	<0.001	0.056	506 (1.9)
Previous AMI (%)	1673 (24.0)	1070 (24.3)	2943 (24.7)	0.554	0.011	508 (1.9)
Ongoing AMI (%)	1772 (26.5)	1174 (27.7)	2987 (26.3)	0.207	0.021	505 (1.9)
Cancer (%)	1385 (19.7)	869 (19.4)	2291 (19.1)	0.605	0.010	508 (1.9)
Previous stroke (%)	852 (12.0)	533 (11.8)	1459 (12.0)	0.955	0.003	510 (1.9)
Ongoing stroke (%)	201 (2.9)	140 (3.2)	380 (3.2)	0.470	0.012	521 (2.0)
Cardiac etiology (%)	2020 (43.2)	1286 (43.2)	3313 (41.7)	0.153	0.021	9797 37.1
Location (%)				<0.001	0.318	0 (0)
Cardiac Care Unit	1087 (14.6)	750 (16.0)	2330 (18.4)			
Intensive Care Unit	523 (7.0)	462 (9.8)	1220 (9.6)			
Operation Theatre	247 (3.3)	89 (1.9)	125 (1.0)			
Emergency Department	754 (10.2)	555 (11.8)	1258 (9.9)			
Out patient clinic, X-day dep, Lab	558 (7.5)	189 (4.0)	244 (1.9)			
Cardiac Catherization laboratory	844 (11.4)	395 (8.4)	610 (4.8)			
Step up unit	41 (0.6)	30 (0.6)	86 (0.7)			
General ward	3128 (42.1)	2116 (45.1)	6637 (52.4)			
Other	244 (3.3)	108 (2.3)	164 (1.3)			
ECG-monitoring (%)	3910 (53.2)	2468 (53.2)	6631 (52.9)	0.895	0.004	357 (1.4)
Witnessed CA (%)	6170 (84.3)	3910 (84.6)	9784 (78.3)	<0.001	0.108	422 (1.6)
Initial arrytmia (%)				<0.001	0.079	5832 (22.1)
VT/VF	1937 (33.5)	1199 (32.7)	2905 (29.0)			
PEA	1585 (27.5)	1029 (28.1)	2693 (26.9)			
Asystole	2252 (39.0)	1440 (39.3)	4423 (44.1)			
Time from CA to call (min (%))				0.149	0.028	4884 (18.5)
0	3281 (51.5)	2088 (51.8)	5542 (49.9)			
1	1855 (29.1)	1181 (29.3)	3316 (29.9)			
2–100	1235 (19.4)	762 (18.9)	2238 (20.2)			
Time from CA to CPR (min (%))				0.053	0.036	3088 (11.7)
0	4790 (69.5)	3138 (71.2)	8521 (71.1)			
1	1391 (20.2)	801 (18.2)	2252 (18.8)			
2–100	716 (10.4)	468 (10.6)	1217 (10.2)			
Time from CA to def (min (%))				0.013	0.064	19,137 (72.5)
0–2	1398 (61.8)	831 (58.6)	2049 (57.5)			
3–4	288 (12.7)	189 (13.3)	467 (13.1)			
4–100	575 (25.4)	399 (28.1)	1049 (29.4)			
Non-adherence to guidelines (%)	350 (7.1)	234 (7.4)	651 (7.5)	0.727	0.009	9535 (36.1)
CPR before CAT arrival (%)	6134 (92.2)	3874 (91.6)	10,774 (93.1)	0.005	0.009	2680 (10.2)
Def before CAT arrival (%)	1157 (18.4)	743 (18.7)	1848 (16.9)	0.008	0.036	4082 (15.5)
Adrenaline (%)	4471 (61.6)	2988 (64.9)	8477 (68.4)	<0.001	0.031	674 (2.6)
Mechanical chest comp (%)	786 (11.1)	481 (10.8)	1180 (9.8)	0.006	0.095	1396 (5.3)
Vacation Period (july-aug) (%)	1064 (14.3)	691 (14.7)	1850 (14.6)	0.809	0.040	0 (0)
Day of the week				<0.001	0.007	0 (0)
Monday	1500 (20.2)	1001 (21.3)	1271 (10.0)			
Tuesday	1508 (20.3)	923 (19.7)	1314 (10.4)			
Wednesday	1568 (21.1)	957 (20.4)	1220 (9.6)			
Thursday	1505 (20.3)	910 (19.4)	1217 (9.6)			
Friday	1345 (18.1)	903 (19.2)	1184 (9.3)			
Saturday	0 (0.0)	0 (0.0)	3209 (25.3)			
Sunday	0 (0.0)	0 (0.0)	3259 (25.7)			
Hospital by size (%)				0.072	0.042	0 (0)
0–99 beds	604 (8.1)	419 (8.9)	1018 (8.0)			
100–250 beds	1022 (13.8)	674 (14.4)	1850 (14.6)			
251–400 beds	2026 (27.3)	1176 (25.1)	3345 (26.4)			
>400 beds	3774 (50.8)	2425 (51.7)	6461 (51.0)			
Non-Academic hospital (%)	4746 (63.9)	2900 (61.8)	7921 (62.5)	0.039	0.029	0 (0)

Table 1: To determine whether the three time groups were statistically different, Chi-square test and one-way ANOVA test used. SMD: the standardized mean difference is the difference between the means for the two groups divided by their standard deviation. Values below 0.1 (10%) are considered inconsequential (i.e., no difference between the groups) Missing: the number and percentage (%) of missing for each variable. CPR: cardiopulmonary resuscitation; CAT: cardiac arrest team.

day to night with 7% (relative survival rate difference). Both CPR and defibrillation was initiated by the ward staff less frequently before CAT arrival during the night compared to the day. This finding is alarming, and we can only speculate as to the reason why this was observed. It's possible that understaffing during the night results in greater delays regarding the chain of survival including initiation of CPR and defibrillation. Less experienced staff during the night is another possible explanation.

4.3. *Vacation effect*

CA during the vacation period (July-august) had lower survival rates (11.4%) and rates of ROSC (5.6%) during the day, but the difference decreased during the evening (−3% and 3.3%) and night (−1.5% and 1.7%). Staffing is often reduced to a minimum during the evening and night under normal circumstances (non-vacation period), and since the staffing cannot be reduced further in the vacation period this might

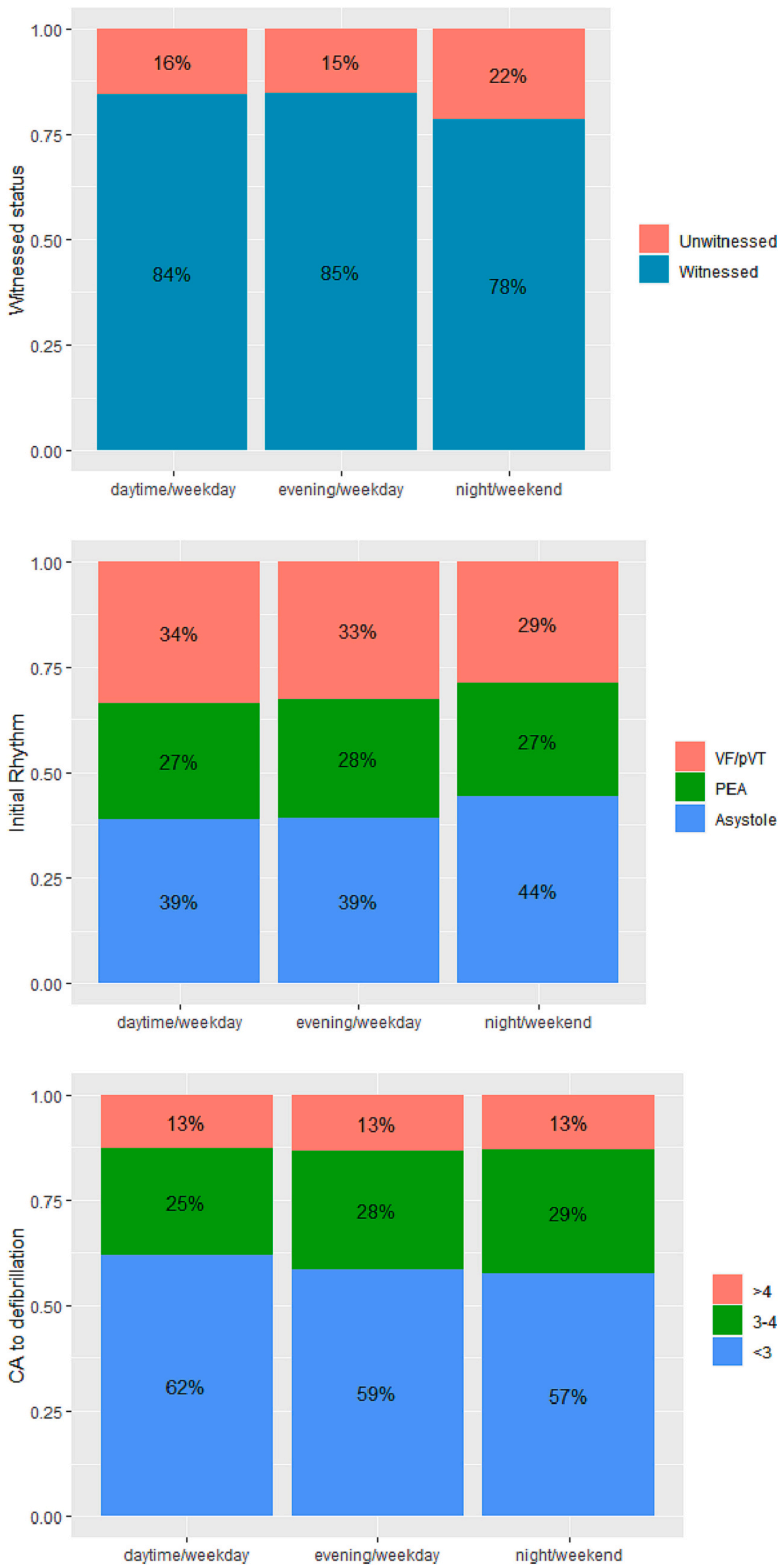


Fig. 1. a-c Witnessed status, initial rhythm and time from CA to defibrillation by time of IHCA.
Fig. 1. a-c: Cumulative bar plots of witnessed status, initial rhythm and time to defibrillation by time category. PEA: Pulseless Electrical Activity; pVT/VF: pulseless Ventricular tachycardia/Ventricular Fibrillation.

Table 2
Survival, ROSC and CPC-score by time of day and day of week.

	7 am-3 pm weekday	3 pm–9 pm weekday	9 pm-7 am + weekend	p	SMD
n	7426	4694	12,674		
Alive at 30 days (%)	2728 (36.8)	1499 (32.0)	3323 (26.2)	<0.001	0.152
ROSC (%)	4989 (67.9)	3080 (66.3)	7546 (60.2)	<0.001	0.108
CPC (%)				0.028	0.081
1	1871 (80.5)	991 (79.1)	2165 (76.6)		
2	290 (12.5)	174 (13.9)	399 (14.1)		
3	138 (5.9)	72 (5.7)	212 (7.5)		
4	18 (0.8)	13 (1.0)	41 (1.5)		
5	6 (0.3)	3 (0.2)	9 (0.3)		

Table 2: To determine whether the three time groups were statistically different, Chi-square test and one-way ANOVA test used. SMD: the standardized mean difference is the difference between the means for the two groups divided by their standard deviation. Values below 0.1 (10%) are considered inconsequential (i.e., no difference between the groups. CPC: cerebral performance category; ROSC: return of spontaneous circulation.

reflect the small decrease in survival during the night. During the vacation period, daytime staffing is often significantly reduced, one possible explanation for the relatively large decrease in survival. The decrease in survival from day to night was smaller during the vacation period compared to the rest of the year, possible a reflection of the larger decrease in staffing and competence when comparing day vs night during the non-vacation period vs the vacation period. Although the association between vacation period and survival did not turn out to be an independent predictor of 30-day survival in the multivariate analysis, the vacation period clearly affect survival indirectly as evidenced by the decrease on both ROSC and survival seen in the unadjusted survival analysis (Table 4 and supplement table 5) and should be taken into account when planning hospital staffing during the vacation period.

4.4. Patient and system characteristics associated with survival

Although not the focus of the present study, in the multivariate logistic regression analysis we confirm the well-established findings (ref IJC) that age, comorbid conditions (heart failure and cancer) and

Table 3
Effect of time of day, hospital and ward characteristics and circumstances at resuscitation on 30-day survival.

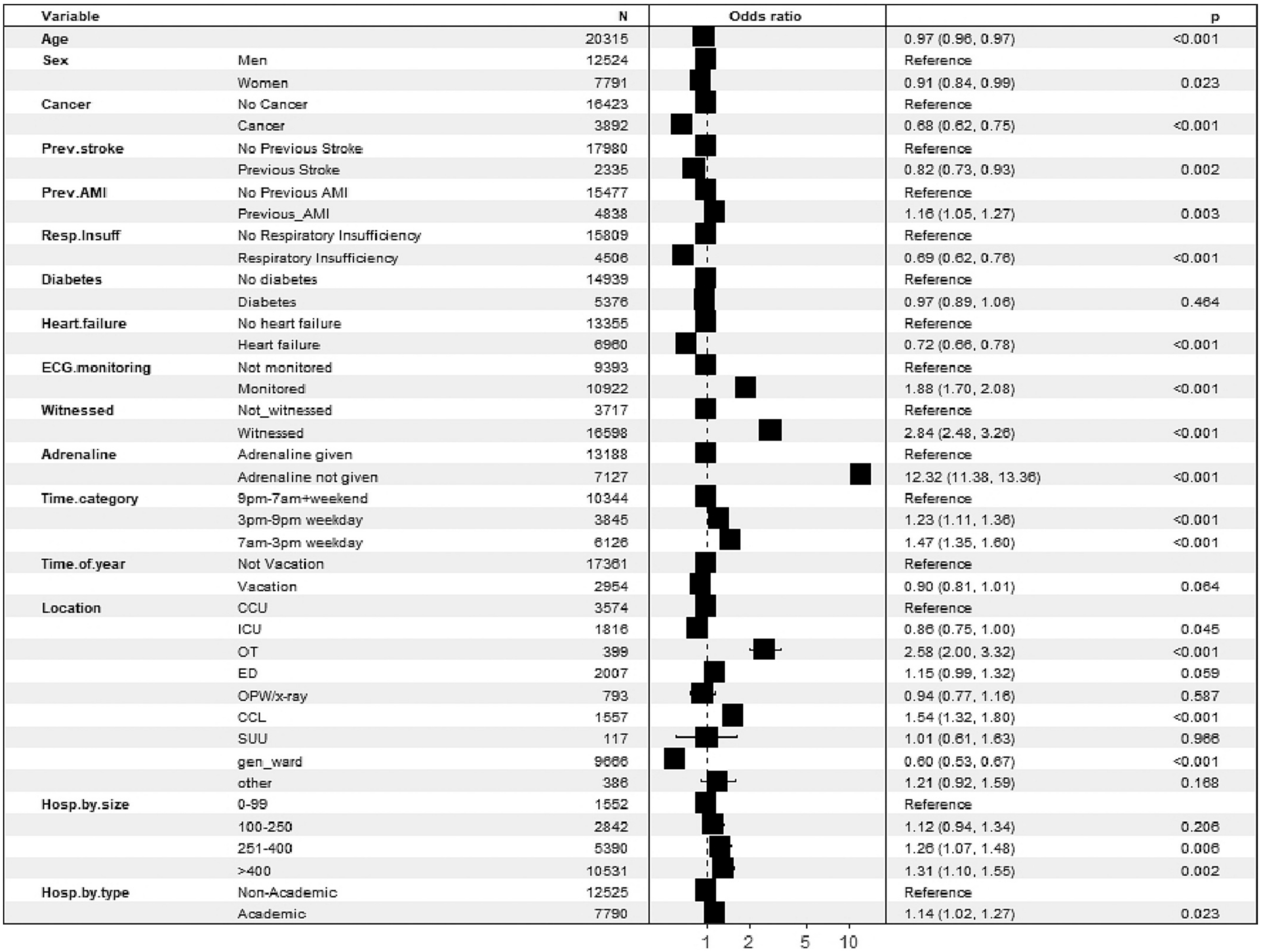
Ward	7 am-3 pm weekday	3 pm–9 pm weekday	9 pm-7 am weekday + am-pm weekend	p	SMD	Relative Survival Rate difference day vs night (%)
CCU	501 (46.1)	337 (44.9)	957 (41.1)	0.011	0.068	−10,8
ICU	199 (38.1)	164 (35.6)	368 (30.2)	0.003	0.111	−20,7
OT	173 (70.0)	43 (48.3)	50 (40.0)	<0.001	0.418	−42,8
ED	257 (34.1)	192 (34.6)	460 (36.6)	0.488	0.034	+7,3
OPW/x-ray	241 (43.2)	51 (27.0)	53 (21.8)	<0.001	0.311	−49,5
CCL	556 (65.9)	237 (60.0)	359 (59.0)	0.016	0.094	−10,5
SUU	14 (35.0)	8 (26.7)	28 (32.6)	0.752	0.121	−6,9
Gen ward	679 (21.7)	437 (20.7)	1000 (15.1)	<0.001	0.115	−30,4
other	108 (44.3)	30 (27.8)	48 (29.3)	0.001	0.232	−33,9
Hospital Size						
0–99	175 (29.0)	90 (21.5)	189 (18.6)	<0.001	0.165	−35,9
100–250	332 (32.5)	174 (25.9)	410 (22.2)	<0.001	0.156	−31,7
251–400	728 (36.0)	368 (31.3)	805 (24.1)	<0.001	0.174	−33
>400	1493 (39.6)	867 (35.8)	1919 (29.7)	<0.001	0.139	−25
Hospital Type						
Academic	1062 (39.6)	641 (35.8)	1468 (30.9)	<0.001	0.122	−22
Non-academic	1666 (35.2)	858 (29.6)	1855 (23.4)	<0.001	0.173	−33,5
Witnessed	6170 (84.3)	3910 (84.6)	9784 (78.3)	<0.001	0.108	−7,1
ECG-monitored	1891 (48.4)	1052 (42.6)	2540 (38.3)	<0.001	0.136	−20,9
Not ECG-monit	809 (23.6)	431 (19.9)	752 (12.7)	<0.001	0.189	−46,2
CPR before CAT	2051 (33.5)	1139 (29.4)	2594 (24.1)	<0.001	0.139	−28,1
Defib before CAT	745 (64.4)	456 (61.4)	1085 (58.7)	0.008	0.078	−8,9

Table 3: To determine whether the three time groups were statistically different, Chi-square test was used. SMD: the standardized mean difference is the difference between the means for the two groups divided by their standard deviation. Relative Survival Rate refers to the relative survival difference from day-time to night-time. Values below 0.1 (10%) are considered inconsequential (i.e., no difference between the groups. CPR: cardiopulmonary resuscitation; CCU: Cardiac Care Unit; ICU: Intensive Care Unit;OT: Operating Theatre; ED: Emergency Department; OPW/x-ray: Out-patient Ward/Radiology Department; CCL: Cardiac Catherization Lab SUU: Step Up Unit; Gen Ward: General Ward: CAT: cardiac arrest team.

Table 4
Effect of time of day and vacation period on ROSC and 30-day survival.

		7 am-3 pm weekday	3 pm–9 pm weekday	9 pm-7 am weekday + am-pm weekend	p	SMD	Relative Survival Rate difference: day vs night
Vacation	n	1064	691	1850			
	30-d surv (%)	346 (32.6)	228 (33.0)	491 (26.6)	<0.001	0.094	−6
	ROSC (%)	675 (64.1)	438 (64.1)	1082 (59.2)	0.011	0.067	−4,9
Not Vacation	n	7426	4694	12,674			
	30-d surv (%)	2728 (36.8)	1499 (32.0)	3323 (26.2)	<0.001	0.152	−10,6
	ROSC (%)	4989 (67.9)	3080 (66.3)	7546 (60.2)	<0.001	0.108	−7,7

Table 4: To determine whether the three time groups were statistically different, Chi-square test was used.SMD: the standardized mean difference is the difference between the means for the two groups divided by their standard deviation. Relative Survival Rate refers to the relative survival difference from day-time to night-time. Values below 0.1 (10%) are considered inconsequential (i.e., no difference between the groups. ROSC: Return of spontaneous circulation.



Variable		N	p (OR, 95% CI)	p
Age		20315	0.97 (0.96, 0.97)	<0.001
Sex	Men	12524	Reference	
	Women	7791	0.91 (0.84, 0.99)	0.023
Cancer	No Cancer	16423	Reference	
	Cancer	3892	0.68 (0.62, 0.75)	<0.001
Prev.stroke	No Previous Stroke	17980	Reference	
	Previous Stroke	2335	0.82 (0.73, 0.93)	0.002
Prev.AMI	No Previous AMI	15477	Reference	
	Previous_AMI	4838	1.16 (1.05, 1.27)	0.003
Resp.Insuff	No Respiratory Insufficiency	15809	Reference	
	Respiratory Insufficiency	4506	0.69 (0.62, 0.76)	<0.001
Diabetes	No diabetes	14939	Reference	
	Diabetes	5376	0.97 (0.89, 1.06)	0.464
Heart.failure	No heart failure	13355	Reference	
	Heart failure	6960	0.72 (0.66, 0.78)	<0.001
ECG.monitoring	Not monitored	9393	Reference	
	Monitored	10922	1.88 (1.70, 2.08)	<0.001
Witnessed	Not_witnessed	3717	Reference	
	Witnessed	16598	2.84 (2.48, 3.26)	<0.001
Adrenaline	Adrenaline given	13188	Reference	
	Adrenaline not given	7127	12.32 (11.38, 13.36)	<0.001
Time.category	9pm-7am+weekend	10344	Reference	
	3pm-9pm weekday	3845	1.23 (1.11, 1.36)	<0.001
	7am-3pm weekday	6126	1.47 (1.35, 1.60)	<0.001
Time.of.year	Not Vacation	17361	Reference	
	Vacation	2954	0.90 (0.81, 1.01)	0.064
Location	CCU	3574	Reference	
	ICU	1816	0.86 (0.75, 1.00)	0.045
	OT	399	2.58 (2.00, 3.32)	<0.001
	ED	2007	1.15 (0.99, 1.32)	0.059
	OPW/x-ray	793	0.94 (0.77, 1.16)	0.587
	CCL	1557	1.54 (1.32, 1.80)	<0.001
	SUU	117	1.01 (0.61, 1.63)	0.966
	gen_ward	9666	0.60 (0.53, 0.67)	<0.001
	other	386	1.21 (0.92, 1.59)	0.168
Hosp.by.size	0-99	1552	Reference	
	100-250	2842	1.12 (0.94, 1.34)	0.206
	251-400	5390	1.26 (1.07, 1.48)	0.006
	>400	10531	1.31 (1.10, 1.55)	0.002
Hosp.by.type	Non-Academic	12525	Reference	
	Academic	7790	1.14 (1.02, 1.27)	0.023

Fig. 2. Forrest plot of adjusted OR for 30-day survival.
Fig.2: Forest plot with the adjusted ORs for 30-day survival for multiple variables. CPR: cardiopulmonary resuscitation; CCU: Cardiac Care Unit; ICU: Intensive Care Unit;OT: Operating Theatre; ED: Emergency Department; OPW/x-ray: Out-patient Ward/Radiology Department; CCL: Cardiac Catherization Lab SUU: Step Up Unit; Gen Ward: General Ward: CAT: cardiac arrest team.

previous medical history (Acute myocardial infarction and stroke) were associated with the chance of 30-day survival. Perhaps surprisingly, out model suggested that female gender might be associated with a decreased chance of survival OR 0.91 (95%CI 0.84–0.99). Conflicting evidence relating to gender and outcome following IHCA have been published (ref) and since the impact of sex and gender was not the focus of the study we avoid drawing any further conclusions.

4.5. Limitations

The SRCR contains data on multiple variables of known importance to CA survival but there is always a risk of residual confounding. The present model was evaluated by calculation of Nagelkerke's R2 = 0.4699. A value of 0.4699 is superior to that obtained in a previous comparable study of IHCA in Sweden (ref) (0.399) but Nagelkerkes R2 is only one of many ways of evaluating logistic model performance. Due to a varying degree of missing information on some variables, not all cases could be included in the final, multivariable, model. To investigate the impact of the missing information, multiple imputations with chained equation (MICE) algorithms were used. ORs obtained with the original and the imputed data sets were similar. The results represent the entire IHCA population in Sweden, and the main findings can be applicable to Sweden and possibly to similar nations and health care systems. How the results translate to other, different, countries and systems is difficult to ascertain and the results of the study need to be repeated to explore their external validity.

5. Conclusion

Patients suffering an IHCA have increased chance of survival during the day vs the evening and the night. The difference in survival was even more pronounced during the evening and night compared to the day when cared for at smaller, non-academic hospitals, general wards and wards without ECG-monitoring capacity. IHCA during the vacation period was associated with a reduced chance of survival. Our conclusion is that there is an inequality of IHCA care over the course of the day/ week, and this should influence policy makers and hospital managers when planning staffing and resource allocation.

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Ethical approval and consent to participate

The study was approved by the regional ethical board in Gothenburg, Sweden (ref No 018–18), which waived the need for informed consent due to the retrospective design of the study.

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CRediT authorship contribution statement

Fredrik Hessulf: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Validation, Visualization, Writing – review & editing. **Johan Herlitz:** Methodology, Visualization, Writing – review & editing. **Peter Lundgren:** Methodology, Visualization, Writing – review & editing. **Solveig Aune:** Methodology, Visualization, Writing – review & editing. **Anna Myredal:** Methodology, Visualization, Writing – review & editing. **Johan Engdahl:** Methodology, Visualization, Writing – review & editing. **Araz Rawshani:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Validation, Visualization, Writing – review & editing.

Declaration of Competing Interest

The authors have no financial disclosures or conflicts of interest.

Data availability

The data sets used and/or analysed during the current study will be available from the corresponding author in response to reasonable requests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcard.2023.03.069.

References

[1] C.M. Bell, D.A. Redelmeier, Mortality among patients admitted to hospitals on weekends as compared with weekdays, N. Engl. J. Med. 345 (9) (2001) 663–668.
[2] D.J. Magid, et al., Relationship between time of day, day of week, timeliness of reperfusion, and in-hospital mortality for patients with acute ST-segment elevation myocardial infarction, Jama 294 (7) (2005) 803–812.
[3] F. Hessulf, et al., Factors of importance to 30-day survival after in-hospital cardiac arrest in Sweden - a population-based register study of more than 18,000 cases, Int. J. Cardiol. 255 (2018) 237–242.
[4] J. Needleman, et al., Nurse staffing and inpatient hospital mortality, N. Engl. J. Med. 364 (11) (2011) 1037–1045.
[5] M.A. Peberdy, et al., Survival from in-hospital cardiac arrest during nights and weekends, Jama 299 (7) (2008) 785–792.
[6] E.J. Robinson, et al., Risk-adjusted survival for adults following in-hospital cardiac arrest by day of week and time of day: observational cohort study, BMJ Qual. Saf. 25 (11) (2016) 832–841.
[7] P. Caillet, et al., Increased mortality for elective surgery during summer vacation: a longitudinal analysis of Nationwide data, PLoS One 10 (9) (2015), e0137754.
[8] I. Jacobs, et al., Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries. A statement for healthcare professionals from a task force of the international liaison committee on resuscitation (American Heart Association, European resuscitation council, Australian resuscitation council, New Zealand resuscitation council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, resuscitation Council of Southern Africa), Resuscitation 63 (3) (2004) 233–249.
[9] F. Hessulf, et al., Adherence to guidelines is associated with improved survival following in-hospital cardiac arrest, Resuscitation 155 (2020) 13–21.
[10] S. van Buuren, Multiple imputation of discrete and continuous data by fully conditional specification, Stat. Methods Med. Res. 16 (3) (2007) 219–242.
[11] U.R. Ofoma, et al., Trends in survival after in-hospital cardiac arrest during nights and weekends, J. Am. Coll. Cardiol. 71 (4) (2018) 402–411.
[12] L.H. Aiken, et al., Nurse staffing and education and hospital mortality in nine European countries: a retrospective observational study, Lancet 383 (9931) (2014) 1824–1830.
[13] Y. Shen, et al., Nurse staffing in large general hospitals in China: an observational study, Hum. Resour. Health 18 (1) (2020) 3.
[14] M.A. Amritzer, et al., Nursing staff ratio and skill mix in Swedish emergency departments: a national cross-sectional benchmark study, J. Nurs. Manag. 29 (8) (2021) 2594–2602.
[15] F. Andrew, H. Hodgson, N. Newbery, Impact of EWTD on patient:doctor ratios and working practices for junior doctors in England and Wales 2009, Clin. Med. 10 (4) (2010) 330–335.
[16] S. Jehrlander (Ed.), En akut bild av Sverige - Kartläggning av akutsjukvårdens organisation och arbetsfördelning, 2018. Stockholm.