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Improved Survival After Out-of-Hospital Cardiac Arrest and Use of Automated External Defibrillators

Marieke T. Blom, PhD, MA, MSc*; Stefanie G. Beesems, MSc*; Petronella C.M. Homma, MSc; Jolande A. Zijlstra, MSc; Michiel Hulleman, MD; Daniel A. van Hoeijen, BSc; Abdennasser Bardai, MD; Jan G.P. Tijssen, PhD; Hanno L. Tan, MD, PhD; Rudolph W. Koster, MD, PhD

Background**—**In recent years, a wider use of automated external defibrillators (AEDs) to treat out-of-hospital cardiac arrest was advocated in The Netherlands. We aimed to establish whether survival with favorable neurologic outcome after out-of-hospital cardiac arrest has significantly increased, and, if so, whether this is attributable to AED use.

Methods and Results**—**We performed a population-based cohort study, including patients with out-of-hospital cardiac arrest from cardiac causes between 2006 and 2012, excluding emergency medical service–witnessed arrests. We determined survival status at each stage (to emergency department, to admission, and to discharge) and examined temporal trends using logistic regression analysis with year of resuscitation as an independent variable. By adding each covariable subsequently to the regression model, we investigated their impact on the odds ratio of year of resuscitation. Analyses were performed according to initial rhythm (shockable versus nonshockable) and AED use. Rates of survival with favorable neurologic outcome after out-of-hospital cardiac arrest increased significantly (N=6133, 16.2% to 19.7%; *P* for trend=0.021), although solely in patients presenting with a shockable initial rhythm (N=2823; 29.1% to 41.4%; *P* for trend<0.001). In this group, survival increased at each stage but was strongest in the prehospital phase (odds ratio, 1.11 [95% CI, 1.06–1.16]). Rates of AED use almost tripled during the study period (21.4% to 59.3%; *P* for trend <0.001), thereby decreasing time from emergency call to defibrillation-device connection (median, 9.9 to 8.0 minutes; *P*<0.001). AED use statistically explained increased survival with favorable neurologic outcome by decreasing the odds ratio of year of resuscitation to a nonsignificant 1.04.

Conclusions**—**Increased AED use is associated with increased survival in patients with a shockable initial rhythm. We recommend continuous efforts to introduce or extend AED programs. **(*Circulation*. 2014;130:00-00.)**

Key Words: defibrillators ■ epidemiology ■ resuscitation ■ survival

Editorial see p 1844
Clinical Perspective on p 8

Out-of-hospital cardiac arrest (OHCA) is a leading cause of death in industrialized countries, affecting 300 000 individuals per year in North America.[1,2] In Europe, 275 000 OHCAs are treated annually.[3] Although the majority of OHCAs (≈70%) have a cardiac cause, in many patients it is the first sign of a cardiovascular disease.[4] OHCA is lethal in most cases.[5,6] Interventions aiming at improved bystander cardiopulmonary resuscitation (CPR) and earlier defibrillation have been implemented in several communities to increase survival rates after OHCA. A recent study[7] showed that national initiatives to increase bystander CPR have improved survival rates in Denmark. In The Netherlands, recent initiatives primarily aimed at decreasing time to first shock delivery by more widespread use of the automated external defibrillator (AED) by dispatched rescuers (firefighter/police team) and by layperson rescuers using publicly available AEDs.[8]

We aimed to establish the following: (1) whether survival with favorable neurologic outcome after OHCA in the community has increased in The Netherlands between 2006 and 2012; (2) at which stage survival rates have increased most (survival to transfer of care at the emergency department (ED), hospital admission, or hospital discharge); and (3) which changes in resuscitation care may explain altered survival rates.

Methods

Setting

The Amsterdam Resuscitation Study (ARREST) is an ongoing, prospective registry of all-cause OHCA in the North Holland province of The Netherlands. ARREST was set up to establish the determinants of outcome of OHCA[8,9] and to gain insight in the genetic, clinical, and

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From the Department of Cardiology, Academic Medical Center, University of Amsterdam, Amsterdam, The Netherlands (M.T.B., S.G.B., P.C.M.H., J.A.Z., M.H., D.A.v.H., A.B., J.G.P.T., H.L.T., R.W.K.); Interuniversity Cardiology Institute Netherlands, Utrecht, The Netherlands (A.B.).

*M.T. Blom and S.G. Beesems contributed equally to this work.

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Correspondence to Hanno L. Tan, MD, PhD, Department of Cardiology, Academic Medical Center, University of Amsterdam, Meibergdreef 9, 1105 AZ, PO Box 22660, 1100 DD, Amsterdam, The Netherlands. E-mail h.l.tan@amc.uva.nl

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pharmacologic determinants of OHCA in the general population.[10,11] The study region covers 2404 km^2 (urban and rural communities) and has a population of 2.4 million people. The present investigation covered the study period January 1, 2006, to December 31, 2012. The medical ethics review board of the Academic Medical Center, University of Amsterdam, approved the study and gave a waiver for obtaining (written) informed consent.

Emergency Medical Service System in the Study Region

In a medical emergency, people dial the national emergency number. When the emergency medical service dispatcher suspects OHCA, 2 ambulances are dispatched, together with a first responder (firefighter/police team) equipped with an AED ("dispatched AED") and qualified to perform basic life support. Ambulance personnel are equipped with a manual defibrillator and qualified to perform advanced life support. The placement of AEDs in public areas ("onsite AED") was stimulated but not centrally controlled or directed.[8] Furthermore, the implementation of changed CPR guidelines (from 15 compressions with 2 ventilations [guidelines in 2000] to 30 compressions with 2 ventilations [30:2 CPR-protocol, guidelines in 2005]) lasted well into 2007.[12]

Data Collection

After each CPR attempt, emergency medical service paramedics routinely send the continuous ECG from their manual defibrillators to the study center. All of the ECGs are stored and analyzed with dedicated software (Code Stat Reviewer 9.0, Physio-Control, Redmond, WA). If an AED is used, ARREST personnel visit the AED site shortly after the OHCA and collect the AED ECG recording using AED-specific software. Data items concerning the CPR procedure (witness of OHCA, bystander CPR performed, and AED use) are collected according to Utstein recommendations[13] by means of a precoded set of questions that ambulance staff are required to answer and by retrieving ambulance data of the event. Data on postresuscitation care (therapeutic hypothermia [TH] or percutaneous coronary intervention [PCI]) were derived from hospital records. Survival was assessed at 3 time points, including survival to transfer of care at ED (hereafter called "survival to ED"), survival to hospital admission, and survival to hospital discharge (information retrieved from hospital records and civic registry).

Definitions

Arrests were deemed to result from cardiac causes unless an unequivocal noncardiac cause was documented (eg, trauma or drowning). We excluded emergency medical service–witnessed cardiac arrests, aborted resuscitation efforts in individuals with a do-not-resuscitate status, and patients with signs of prolonged death. Defibrillator connection time was defined as the time interval between emergency call and connection of the defibrillator device to the patient. Continuous ECGs from manual defibrillators (ambulance) or AEDs were analyzed to determine first rhythm. First rhythms were categorized as shockable (ventricular tachycardia/ventricular fibrillation) or nonshockable (asystole or pulseless electric activity). The use of 30:2 CPR protocol was defined as a dichotomous variable and was determined by analyzing the impedance signal in the continuous ECG from AED or manual defibrillator. Neurologic outcome on the cerebral performance category (CPC) scale was assessed by reviewing hospital charts of patients who survived until hospital discharge. Category 1 represents good cerebral performance; category 2, moderate cerebral disability; category 3, severe cerebral disability; category 4, coma or vegetative state; and category 5, death. Survival with favorable neurologic outcome was defined as CPC score ≤2.[13–15]

Statistical Analysis

To evaluate changes in baseline resuscitation characteristics, hospital care, and survival rates by calendar year, we calculated a *P* value for trend using a χ^2 test (linear-by-linear) for dichotomous data. For continuous variables, we used linear regression in case of normally distributed data; for non-normally distributed data, we used the Jonckheere-Terpstra test. We evaluated changes in in-hospital care (TH

Table 1. Baseline and Operational Patient Characteristics

Baseline Characteristics	2006	2007	2008	2009	2010	2011	2012	*P* for Trend	Missing Data, n (%)
OHCA patients, n	851	876	874	871	887	900	874		
Mean age, (SD), y	65.0 (15.7)	65.1 (15.9)	65.1 (15.6)	65.9 (15.0)	67.6 (14.6)	66.3 (16.0)	67.1 (14.1)	<0.001	26 (0.4)
Men, n (%)	639 (75.1)	640 (73.1)	630 (72.4)	644 (73.9)	622 (70.1)	638 (71.0)	632 (72.3)	0.065	5 (0.1)
OHCA at public location, n (%)	256 (30.1)	260 (29.7)	287 (32.9)	262 (30.1)	246 (28.0)	244 (27.3)	243 (28.1)	0.054	29 (0.5)
Witnessed OHCA, n (%)	662 (78.2)	672 (77.2)	674 (77.9)	637 (73.9)	647 (74.6)	628 (70.5)	623 (71.6)	<0.001	61 (1.0)
Bystander CPR performed, n (%)	557 (65.8)	612 (70.5)	605 (70.9)	623 (73.0)	635 (73.6)	673 (76.0)	699 (81.2)	<0.001	104 (1.7)
AED use, n (%)	182 (21.4)	210 (24.0)	208 (23.8)	294 (33.8)	385 (43.5)	461 (51.2)	518 (59.3)	<0.001	1 (0.0)
Shockable first rhythm, n (%)	429 (52.2)	413 (48.6)	416 (48.7)	391 (46.9)	391 (46.2)	426 (49.1)	392 (45.1)	0.013	192 (3.1)
Protocol 30:2 used, n (%)	170 (24.7)	546 (84.1)						<0.001	390 (22.6)
Time from call to defibrillator connection*	9.9 (7.6–12.4)	10.7 (8.5–13.2)	9.6 (7.2–12.6)	9.7 (7.2–12.5)	9.0 (7.1–11.4)	7.6 (5.4–10.5)	8.0 (6.1–10.3)	<0.001	390 (6.4)
Defibrillation shock <6 min, n (%)	48 (9.2)	49 (9.6)	61 (12.2)	59 (12.5)	56 (12.0)	121 (24.8)	97 (21.7)	<0.001	NA
Admitted to hospital, n	313	309	324	298	343	349	335		
TH performed, n (%)	215 (69.1)	203 (66.3)	232 (71.8)	218 (75.7)	264 (78.8)	253 (74.6)	238 (75.8)	0.001	55 (2.4)
PCI performed, n (%)	96 (30.9)	113 (36.8)	115 (35.7)	118 (40.0)	120 (35.5)	124 (35.7)	123 (39.0)	0.129	36 (1.6)

All of the *P* values were calculated with the χ^2 (linear by linear) except for the variable mean age, which was calculated with linear regression and the variable EMS response time with the Jonckheere-Terpstra test. AED indicates automated external defibrillator; CPR, cardiopulmonary resuscitation; NA, not applicable; OHCA, out-of-hospital cardiac arrest; PCI, percutaneous coronary intervention; and TH, therapeutic hypothermia.

*Connection time of AED or manual defibrillator is shown as median (Q1-Q3), min.

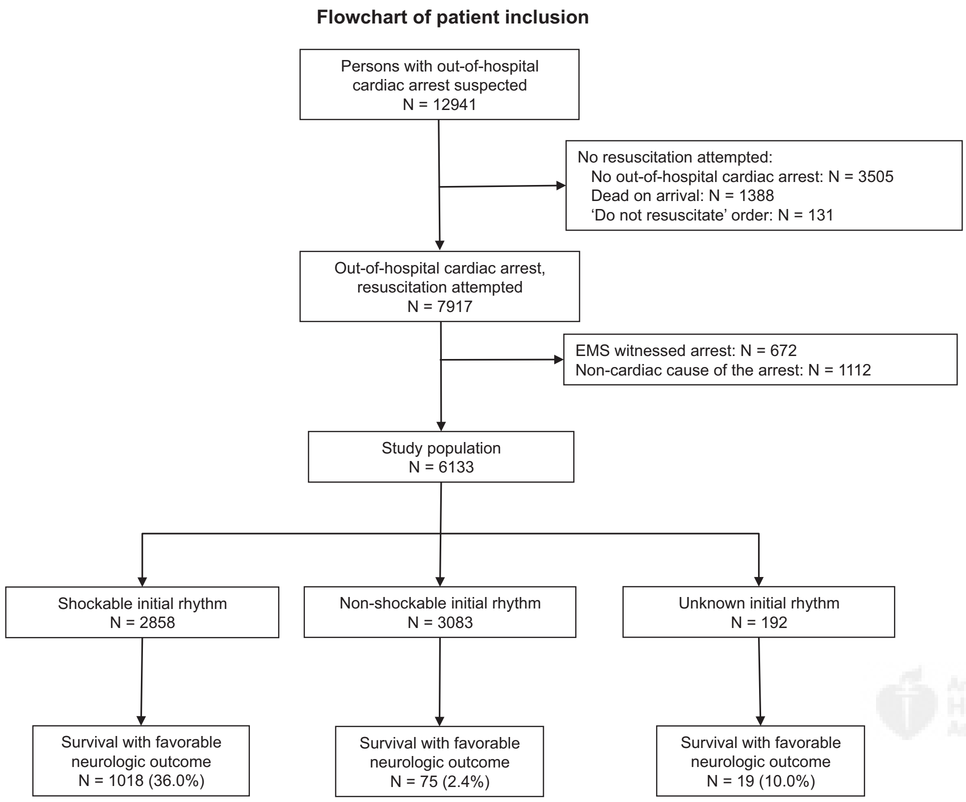

Figure 1. Flowchart of patient inclusion.

or PCI performed) in patients admitted to the hospital. We assessed whether survival with favorable neurologic outcome had improved over time using logistic regression analysis, with the independent variable of year of resuscitation as a continuous variable. Survival with favorable neurologic outcome was regressed in the total population and according to first rhythm (shockable or nonshockable). Survival per stage (to ED, to hospital admission, or to hospital discharge) was regressed by selecting patients who had survived to the previous stage.

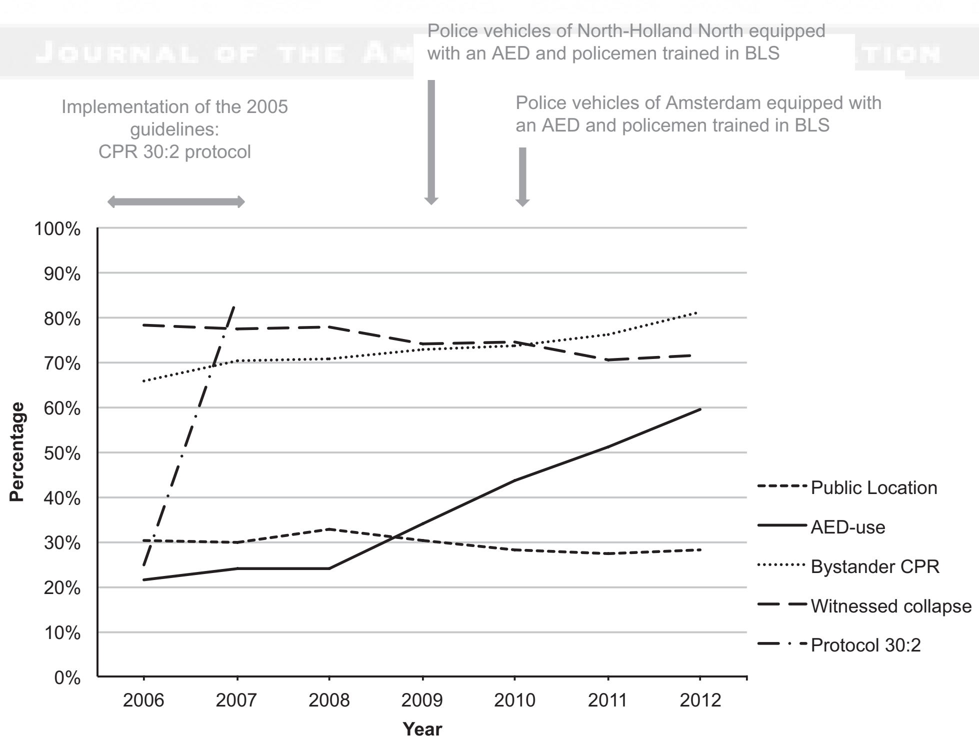

Figure 2. Prehospital resuscitation care characteristics, 2006–2012. AED indicates automated external defibrillator; BLS, basic life support; and CPR, cardiopulmonary resuscitation.

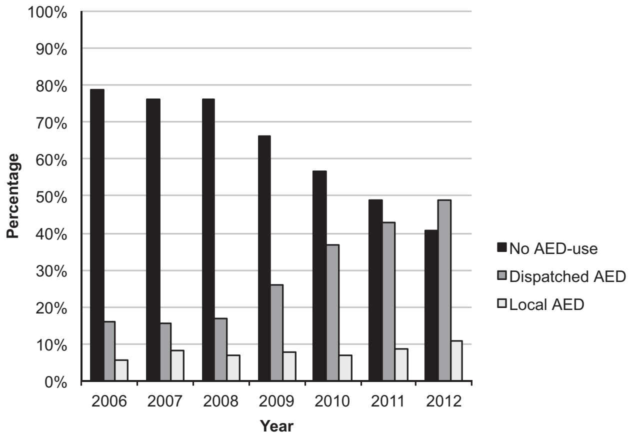

Figure 3. Percentage of resuscitations according to (type of) automated external defibrillator (AED) use, per year.

To establish which factor contributed to increased rates of survival with favorable neurologic outcome over time, we first performed univariable logistic regression analysis, with year of resuscitation as the independent variable. We then analyzed which variables changed significantly during the study period and were associated with survival with favorable neurologic outcome. We then added such a variable to the model to determine whether the odds ratio (OR) of year of resuscitation would be adjusted toward the 1, indicating that the effect of year of resuscitation is (at least partly) explained by that variable. Next, we stratified the analysis according to AED use and repeated the analysis.

Hospital care variables were evaluated in patients admitted to the hospital alive. CPR protocol was assessed for the years 2006 and 2007, because implementation of protocol change occurred in that period.[12] Only these years were used when we analyzed the association between protocol and survival with favorable neurologic outcome.

To test whether missing data introduced bias, we constructed 5 imputed data sets with multivariate imputation models using information from all of the prehospital OHCA variables presented in Table 1. Because AED use is strongly associated with other variables, we stratified the data according to AED use (onsite AED, dispatched AED, or no AED use) before running imputation models. Missing data on outcome were not imputed. We then compared estimates from the observed data set with the estimates from the imputed data sets. In addition, we performed a sensitivity analysis limiting our definition of survival with favorable neurologic outcome to CPC score 1.

Continuous variables were described as means and SDs or medians and interquartile range where appropriate, and categoric variables as absolute numbers and percentages. *P* values <0.05 were considered statistically significant. All of the data were analyzed using the statistical software package of SPSS (SPSS for Mac, version 20.0, SPSS Inc, Chicago, IL).

Results

A total of 6133 OHCAs with cardiac cause (total study cohort) were identified (Figure 1 and Table I in the online-only Data Supplement). The incidence of emergency medical service treated OHCA (with/without cardiac cause) did not change during the study period. Patient and resuscitation characteristics are shown in Table 1; Figure 2 shows changes over time, along with the introduction of dispatched police AEDs. There was a large increase over time in AED use (2006, 21.4%; 2012, 59.3%; *P*<0.001 for trend). The largest increase concerned dispatched AEDs (16.0% to 48.7% of all resuscitations), but the use of onsite AEDs increased as

Table 2. Trends in Survival With Favorable Neurologic Outcome After Out-of-Hospital Cardiac Arrest, All Patients, and According to Initial Rhythm; Survival per Stage in Patients With Shockable First Rhythm

Survival	2006 (n=851)	2007 (n=876)	2008 (n=873)	2009 (n=866)	2010 (n=881)	2011 (n=893)	2012 (n=852)	*P* for Trend	OR (95% CI)	Missing Data, n (%)
Survival with favorable neurologic outcome after OHCA*										
All patients (n=6092)	138 (16.2)	135 (15.4)	183 (21.0)	150 (17.3)	166 (18.8)	172 (19.3)	168 (19.7)	0.021	1.04 (1.01–1.07)	41 (0.7)
Shockable first rhythm (n=2823)	125 (29.1)	121 (29.3)	171 (41.1)	141 (36.5)	147 (37.9)	159 (37.9)	154 (41.4)	<0.001	1.08 (1.04–1.12)	35 (1.2)
Nonshockable first rhythm (n=3079)	12 (3.1)	9 (2.1)	9 (2.1)	7 (1.6)	14 (3.1)	11 (2.5)	13 (2.7)	0.752	1.02 (0.91–1.14)	4 (0.1)
Unknown first rhythm (n=190)	1 (3.4)	5 (18.5)	3 (15.8)	2 (5.3)	5 (12.8)	2 (6.1)	1 (20.0)	1.000	1.00 (0.76–1.30)	2 (1.0)
Survival per stage in patients with shockable first rhythm										
To ED	324 (75.5)	332 (80.4)	339 (81.5)	324 (82.9)	339 (86.7)	351 (82.4)	339 (86.5)	<0.001	1.11 (1.06–1.16)	0 (0.0)
Admission to hospital	239 (73.8)	233 (70.2)	262 (77.3)	238 (73.7)	261 (77.0)	278 (79.7)	259 (76.6)	0.028	1.05 (1.01–1.11)	4 (0.2)
Hospital discharge	139 (58.2)	130 (55.8)	180 (68.7)	150 (64.1)	159 (60.9)	174 (72.8)	178 (69.5)	0.016	1.06 (1.01–1.11)	8 (0.5)
With favorable neurologic outcome*	125 (89.9)	121 (93.4)	171 (95.0)	141 (94.0)	147 (94.2)	159 (93.5)	154 (95.1)	0.167	1.09 (0.96–1.24)	23 (2.1)

Values are number of patients (%). Analysis survival to ED, n=2858 (all patients with shockable initial rhythm). Analysis survival to hospital, n=2344 (all patients with shockable initial rhythm transported to ED alive). Analysis survival to hospital discharge, n=1762 (all patients with shockable initial rhythm admitted to hospital alive). Analysis survival with favorable neurologic outcome, n=1087 (all patients with shockable initial rhythm discharged from hospital alive). ED indicates emergency department; OHCA, out-of-hospital cardiac arrest; OR, odds ratio; and VF/VT, ventricular fibrillation/ventricular tachycardia.

*All of the patients in whom the neurologic state at discharge (cerebral performance category score) was unknown were not included in this analysis (all patients, n=41; patients with shockable initial rhythm, n=23).

Table 3. Distribution of CPC Scores Among Surviving Patients (All Types of First Rhythms) per Year

	2006	2007	2008	2009	2010	2011	2012
CPC 1	111 (72.5)	124 (85.5)	148 (76.7)	124 (78.0)	120 (67.0)	150 (81.1)	136 (76.8)
CPC 2	27 (17.6)	11 (7.6)	35 (18.1)	26 (16.4)	46 (25.7)	22 (11.9)	32 (18.1)
CPC 3	13 (8.5)	10 (6.9)	6 (3.1)	9 (5.7)	13 (7.3)	9 (4.9)	8 (4.5)
CPC 4	2 (1.3)	0 (0.0)	4 (2.1)	0 (0.0)	0 (0.0)	4 (2.2)	1 (0.6)
Total	153 (100)	145 (100)	193 (100)	159 (100)	179 (100)	185 (100)	177 (100)

Data are n (%). Surviving patients with all types of first rhythms, n=1191; CPC score missing, n=24. In all survivors, *P* for trend=0.783. In survivors with CPC score 1 or 2, *P* for trend=0.413. CPC indicates cerebral performance category; CPC 1, good cerebral performance; CPC 2, moderate cerebral disability; CPC 3, severe cerebral disability; and CPC 4, coma or vegetative state.

well (5.4% to 10.6%; Figure 3). Other statistically significant changes that were assumed to increase the rate of survival with favorable neurologic outcome were increased bystander CPR rates (65.8% to 81.2%; *P*<0.001) and decreased defibrillator connection time (9.9 to 8.0 minutes; *P*<0.001), resulting in increased proportion of delivered shocks <6 minutes (9.2% to 21.7%; *P*<0.001). Moreover, wide application of the 30:2 CPR protocol occurred in the period from 2006 to 2007. Changes that may reduce the rate of survival with favorable neurologic outcome were also observed, including decreased proportions of witnessed OHCA (78.2% to 70.5%; *P*<0.001) and shockable first rhythm (52.2% to 45.1%; *P*<0.013). Among patients who were admitted to the hospital, PCI treatment did not increase significantly during the study period. An increase in TH treatment was observed (69.1% to 75.8%; *P*=0.001); however, TH treatment was not provided (n=593), either because patients were already conscious (n=369; 62.2%) or because only palliative care was given (n=138; 23.3%). Only 86 patients (14.5%) did not receive indicated TH treatment, clustered in the first 2 study years; therefore, further analyses were not performed.

Changes in Survival Rates

Table 2 shows rates of survival with favorable neurologic outcome per year. In the total study cohort, a statistically significant increase in the rate of survival with favorable neurologic outcome occurred from 16.2% in 2006 to 19.7% in 2012 (OR, 1.04 [95% CI, 1.01–1.07]). This was largely because of improved rates among patients with shockable first rhythm (29.1% to 41.4%; OR, 1.08 [95% CI, 1.04–1.12]). Because no change in the rate of survival with favorable neurologic outcome was observed among patients with nonshockable first rhythm (3.1% to 2.7%; OR, 1.02 [95% CI, 0.91–1.14]), we performed no further analyses in this patient group.

Among patients with shockable first rhythm, survival rates increased at each stage. The largest increase occurred in the first stage (to ED, 75.5% to 86.5%; OR, 1.11 [95% CI, 1.06–1.16]). Among patients who reached the ED alive, the proportion of those admitted to the hospital alive also increased (73.8% to 76.6%; OR, 1.05 [95% CI, 1.01–1.11]), as did the proportion of patients who were discharged alive after admission to the hospital (58.2% to 69.5%; OR, 1.06 [95% CI, 1.01–1.11]). The proportion of patients who were neurologically intact at hospital discharge remained high throughout the study period (89.9% to 95.1%; OR, 1.09 [95% CI, 0.96–1.24]). Table 3 shows CPC scores of surviving patients (all types of first rhythms) per year.

Explaining Increased Survival Rates

To explore which changes might explain the increase in survival with favorable neurologic outcome in patients with a shockable first rhythm, we analyzed which variables changed the crude OR of year of resuscitation toward 1 when added to the logistic regression model. Variables not included in the analyses were male sex and PCI treatment (no change), as well as 30:2 CPR protocol (no association[16]; Table II in the online-only Data Supplement). Table 4 shows the (adjusted) ORs of year of resuscitation with each consecutively added variable. Only 2 variables decreased the OR of year of resuscitation to a nonsignificant level, AED use and time to

Table 4. Odds Ratios of Year of Resuscitation in Regression Models With Survival With Favorable Neurologic Outcome in Patients With Shockable Initial Rhythm, Crude and With Subsequently Added Single Covariates, All Patients, and According to AED Use

	Shockable First Rhythm					
	All Patients		AED Use		No AED Use	
	OR (95%CI)	*P* Value	OR (95%CI)	*P* Value	OR (95%CI)	*P* Value
Year of resuscitation, crude OR	1.08 (1.04–1.13)	<0.001	1.01 (0.95–1.07)	0.867	1.07 (1.01–1.13)	0.018
Year of resuscitation, age (decades) adjusted OR	1.09 (1.05–1.14)	<0.001	1.01 (0.95–1.07)	0.743	1.08 (1.02–1.14)	0.007
Year of resuscitation, public location adjusted OR	1.09 (1.04–1.13)	<0.001	1.00 (0.94–1.07)	0.905	1.08 (1.02–1.14)	0.006
Year of resuscitation, witnessed OHCA adjusted OR	1.09 (1.05–1.13)	<0.001	1.01 (0.95–1.08)	0.663	1.08 (1.02–1.14)	0.011
Year of resuscitation, bystander CPR adjusted OR	1.07 (1.03–1.12)	<0.001	1.01 (0.95–1.07)	0.871	1.08 (1.02–1.14)	0.008
Year of resuscitation, AED use adjusted OR	1.04 (1.00–1.08)	0.064	NA		NA	
Year of resuscitation, defibrillator connection time (min) adjusted OR	1.03 (0.99–1.07)	0.150	0.99 (0.93–1.06)	0.790	1.07 (1.01–1.14)	0.019

AED indicates automated external defibrillator; CPR, cardiopulmonary resuscitation; NA, not applicable; OHCA, out-of-hospital cardiac arrest; and OR, odds ratio.

defibrillator connection. To further explore what might explain the observed increased rates of survival with favorable neurologic outcome, we stratified patients according to AED use (Table 4). In the patient group that was treated with an AED, the OR of year of resuscitation was no longer significant, indicating that, in this group, AED use statistically explained the improved survival rates. Adding other variables to the model did not show relevant changes. In the patient group without AED use, the crude OR of year of resuscitation was still statistically significant (1.07 [95% CI, 1.01–1.13]); none of the studied variables significantly impacted the OR for the year of resuscitation. Repeating the analysis with imputation for missing data showed comparable results (Tables III and IV in the online-only Data Supplement).

Table 5 shows survival with favorable neurologic outcome per time-to-shock category in patients with a shockable initial rhythm. These results confirm that the percentage of survival with favorable neurologic outcome improves with decreased time to shock, as expected. Of note, in surviving patients with a time to shock of >10 minutes (n=232), in as many as 83.2% of the resuscitations, bystander CPR was performed.

Table 5. Time to Shock and Survival With Favorable Neurologic Outcome in Patients With Shockable First Rhythm

Time to Shock, min	Survival With Favorable Neurologic Outcome, n (%)
0–2	81 (71.1)
2–4	78 (63.4)
4–6	121 (52.4)
6–8	212 (42.3)
8–10	196 (37.7)
10–12	127 (27.7)
>12	155 (20.9)

Numbers are n (%). All of the patients with shockable first rhythm, n=2858; cerebral performance category score missing, n=35; time to shock missing, n=133.

Sensitivity Analyses

A sensitivity analysis limiting the definition of survival with favorable neurologic outcome to CPC score 1 showed that, again, survival increases, but in the total patient group statistical significance was not reached (*P*=0.096 for trend). When stratified according to initial rhythm, we observed again a statistically significant increase in survival (*P*=0.002 for trend). With this strict definition, again only AED use and time to defibrillator decreased the OR of year of resuscitation to a nonsignificant level when added to the model. Adding AED use now decreased the OR of year of resuscitation to 1.01 (*P*=0.625), thereby showing an even stronger association.

Discussion

Main Findings

We report an increase in rates of survival with favorable neurologic outcome after OHCA (16.2% to 19.7%) in The Netherlands during a 7-year study period, although solely in patients presenting with a shockable rhythm (29.1% to 41.4%). Survival increased at each stage of the resuscitation process, but the strongest trend was found in the prehospital phase (OR, 1.11). The proportion of surviving patients that had a favorable neurologic outcome at discharge remained high throughout the study period (89.9% to 95.1%). Rates of AED use almost tripled during the study period (21.4% to 59.3%), thereby decreasing the time from call to defibrillator connection and statistically explaining the increase in survival rate for a considerable part.

Survival Improvements in the Dutch Setting at Every Stage

When compared with other countries, Dutch prehospital resuscitation care already had high standards at the beginning of our study period.[17,19] For instance, the increased bystander CPR rate to 44.9% in 2010 in Denmark as reported by Wissenberg et al[7] is still low compared with the 65.8% of resuscitations with bystander CPR at the start of our study period in 2006. Similarly, the Danish increase in 30-day survival (to 10.8% in 2010) is much lower than the rate of survival with favorable neurologic outcome in 2006 (16.2%) in the present study. Nonetheless, even in The Netherlands, there was ample room for improvement.

The survival analysis at each consecutive stage of resuscitation care showed that the largest increase was found in the prehospital phase, indicating that the large investments in improvement of prehospital care had the desired effects. The subsequent increased survival rate after hospital admission clearly shows that improving prehospital survival rates after OHCA is not merely changing the place to die, as some skeptics of layperson defibrillation have suggested. Indeed, in accordance with a study by Hollenberg et al,[20] we also show that survival with favorable neurologic outcome among patients who were admitted to the hospital alive was still strongly associated with prehospital factors (Table V in the online-only Data Supplement). Nonetheless, in the patient group in which no AED was used, we still observed an increase in survival that was not explained by the studied prehospital variables; other (in-hospital) factors may play a role here.

Policy Measures

Previous studies[21,22] described that time to defibrillation decreased and survival increased with the implementation of police AED programs. In our study region, apart from the already involved firefighters, starting in 2009 all police teams were equipped with an AED and trained in basic life support, thereby steadily increasing the number of available dispatched AEDs. Furthermore, The Netherlands Heart Foundation has launched the "6-minute zone" campaign in 2007, aiming to raise AED awareness in the community to increase the number of resuscitation attempts in which a defibrillation shock was delivered within 6 minutes after the first call to the national emergency number. The proportion of resuscitations with connection times <6 minutes increases when an AED is used, in both onsite and dispatched AEDs. Although the survival benefit of onsite AED use is very large on the patient level, the more modest survival benefit of the increasing use of dispatched AEDs[8] will have a large impact at the population level. At present, new regional programs are being implemented in the study area in which registered volunteers are alerted by text message to their mobile telephone if an OHCA has occurred in their vicinity and are directed to the OHCA victim or the closest onsite AED. The number of OHCAs with AED use is thus likely to increase further.

Limitations

First, our analyses are based on observational data. Hence, we can only calculate associations and perform statistical analyses to support the notion that our findings are explained by certain factors. Because of our study design, we cannot prove causality. Second, we did not include more detailed covariates of the resuscitation process, such as the quality of given CPR and the time in recurrent ventricular fibrillation, although these variables are of importance for survival with favorable neurologic outcome.[16,23] Third, we had to accept a modest level of missing data (Table 2). However, analyses with our imputed data sets did not show relevant differences regarding our main estimates when compared with the observed data sets. Lastly, although we do acknowledge the importance of in-hospital postresuscitation care, the main focus of our study was on prehospital parameters. Therefore, we were unable to provide more detailed information about in-hospital care beyond the application of TH and PCI.

Conclusions

We report a significant increase in rates of survival with favorable neurologic outcome after OHCA between 2006 and 2012 in The Netherlands in patients presenting with a shockable rhythm. Survival increased at each stage of the resuscitation process, but the strongest trend was observed in the prehospital phase. AED use rates almost tripled during the study period, thereby decreasing the time from call to defibrillator connection. Increased AED use is associated with increased survival in patients with a shockable initial rhythm. We recommend continuous efforts to improve resuscitation care, with strong emphasis on introducing or extending AED programs, involving both dispatched AEDs and onsite AEDs.

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Disclosures

None.

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CLINICAL PERSPECTIVE

Out-of-hospital cardiac arrest (OHCA) is a leading cause of death in industrialized countries. Interventions aimed at improved bystander cardiopulmonary resuscitation and earlier defibrillation have been implemented in several communities to increase survival rates after OHCA. In The Netherlands, national initiatives were primarily focused on decreasing time to first shock by more widespread use of the automated external defibrillator (AED) by dispatched rescuers (firefighter/police team) and by layperson rescuers using publicly available AEDs. We aimed to establish whether survival with favorable neurologic outcome after OHCA has significantly increased over time, and, if so, whether this is attributable to AED use. We performed a population-based cohort study in The Netherlands, including patients with OHCA from cardiac causes between 2006 and 2012, excluding emergency medical service–witnessed arrests. Survival rates with favorable neurologic outcome after OHCA increased (16.2% to 19.7%; P for trend=0.021), although only in patients presenting with a shockable rhythm (29.1% to 41.4%; P for trend<0.001). Survival rates increased at each stage of the resuscitation process; the strongest increase occurred in the prehospital phase. The proportion of surviving patients with favorable neurologic outcome remained high throughout the study period (89.9% to 95.1%). Rates of AED use almost tripled during the study period (21.4% to 59.3%; P for trend<0.001), thereby decreasing time from emergency call to defibrillation device connection (median, 9.9 to 8.0 minutes; P<0.001), resulting in an increased proportion of delivered shocks that were <6 minutes (9.2% to 21.7%; P<0.001). Increased AED use is associated with increased survival in patients with a shockable initial rhythm. We recommend continuous efforts to improve resuscitation care, with strong emphasis on introducing or extending AED programs, and involving both dispatched AEDs and onsite AEDs.