ORIGINAL ARTICLE

Bystander Efforts and 1-Year Outcomes in Out-of-Hospital Cardiac Arrest

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ABSTRACT

BACKGROUND

The effect of bystander interventions on long-term functional outcomes among survivors of out-of-hospital cardiac arrest has not been extensively studied.

METHODS

We linked nationwide data on out-of-hospital cardiac arrests in Denmark to functional outcome data and reported the 1-year risks of anoxic brain damage or nursing home admission and of death from any cause among patients who survived to day 30 after an out-of-hospital cardiac arrest. We analyzed risks according to whether bystander cardiopulmonary resuscitation (CPR) or defibrillation was performed and evaluated temporal changes in bystander interventions and outcomes.

RESULTS

Among the 2855 patients who were 30-day survivors of an out-of-hospital cardiac arrest during the period from 2001 through 2012, a total of 10.5% had brain damage or were admitted to a nursing home and 9.7% died during the 1-year follow-up period. During the study period, among the 2084 patients who had cardiac arrests that were not witnessed by emergency medical services (EMS) personnel, the rate of bystander CPR increased from 66.7% to 80.6% (P<0.001), the rate of bystander defibrillation increased from 2.1% to 16.8% (P<0.001), the rate of brain damage or nursing home admission decreased from 10.0% to 7.6% (P<0.001), and all-cause mortality decreased from 18.0% to 7.9% (P=0.002). In adjusted analyses, bystander CPR was associated with a risk of brain damage or nursing home admission that was significantly lower than that associated with no bystander resuscitation (hazard ratio, 0.62; 95% confidence interval [CI], 0.47 to 0.82), as well as a lower risk of death from any cause (hazard ratio, 0.70; 95% CI, 0.50 to 0.99) and a lower risk of the composite end point of brain damage, nursing home admission, or death (hazard ratio, 0.67; 95% CI, 0.53 to 0.84). The risks of these outcomes were even lower among patients who received bystander defibrillation as compared with no bystander resuscitation.

CONCLUSIONS

In our study, we found that bystander CPR and defibrillation were associated with risks of brain damage or nursing home admission and of death from any cause that were significantly lower than those associated with no bystander resuscitation. (Funded by TrygFonden and the Danish Heart Foundation.)

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Survival after out-of-hospital cardiac arrest has increased in several countries after improvements in bystander interventions and postresuscitation care.[1-9] Despite these improvements, little is known about long-term functional outcomes, including how bystander interventions (cardiopulmonary resuscitation [CPR] and defibrillation) influence these outcomes and whether the outcomes have changed over time.[7,10,11]

Survivors of out-of-hospital cardiac arrest may sustain brain injury due to inadequate cerebral perfusion during cardiac arrest. Anoxic brain damage after out-of-hospital cardiac arrest may result in a need for constant care or assistance with activities of daily living. Persons with anoxic brain damage may therefore require nursing home care after discharge.[12,13] The evaluation of care needs is an integral part of neurologic outcome scales, such as the modified Rankin scale, and poor scores on such scales have been correlated with low quality of life.[14-16] Bystander chest compressions and the use of an automated external defibrillator may reduce neurologic impairment by preserving cerebral perfusion and shortening the time to restoration of spontaneous circulation, with potential implications for initiatives and strategies to increase bystander CPR and public-access defibrillation.[17]

We examined the risk of anoxic brain damage or nursing home admission among 30-day survivors of out-of-hospital cardiac arrest in Denmark during a 1-year follow-up period; outcomes were analyzed according to whether patients received bystander CPR and bystander defibrillation. We also examined temporal changes in these bystander interventions and outcomes during the period from 2001 through 2012.

METHODS

STUDY SETTING

Denmark covers 16,573.44 mi^2; during 2001 through 2012, the population increased from approximately 5,355,000 to approximately 5,581,000 persons. Since June 1, 2001, emergency medical services (EMS) personnel in Denmark have systematically reported every case of out-of-hospital cardiac arrest for which bystanders or EMS had initiated resuscitation to the Danish Cardiac Arrest Registry. For details regarding this registry, see the Methods section of the Supplementary Appendix, available with the full text of this article at NEJM.org. Complete case capture is pursued through contractual agreements obligating EMS personnel to complete a short case-report form for every out-of-hospital cardiac arrest. On the basis of data from the registry, the incidence of out-of-hospital cardiac arrest in Denmark has been stable during the period from 2001 through 2012 and is similar to incidences calculated from European and U.S. registry data.[18-20]

In Denmark, basic life support ambulances staffed with technicians or paramedics are dispatched to out-of-hospital cardiac arrest emergencies, and mobile emergency care units staffed with paramedics or anesthesiologists are dispatched in parallel. During 2001 through 2012, multiple nationwide initiatives were undertaken to improve bystander interventions and postresuscitation care (Table S1 in the Supplementary Appendix).

STUDY POPULATION AND DESIGN

We included all 30-day survivors of cardiac arrest who were 18 years of age or older and listed in the Danish Cardiac Arrest Registry during the period from 2001 through 2012. Patients who were in nursing homes or who had anoxic brain damage before the out-of-hospital cardiac arrest were excluded.

Follow-up data for study patients were obtained from nationwide registries. All residents in Denmark have a unique Civil Personal Registration Number that is used in all health care contacts and reported to the Danish Cardiac Arrest Registry, which facilitates linkage to other nationwide registries.[21]

This study was approved by the Danish Data Protection Agency. In Denmark, ethics approval is not required for registry-based studies. Further details concerning ethics are provided in the Methods section in the Supplementary Appendix.

The study was supported by the Danish foundation TrygFonden and the Danish Heart Foundation. The Danish Cardiac Arrest Registry is supported by TrygFonden, which has no commercial interests in the field of cardiac arrest. None of these institutions had any influence on study design or conduct; collection, management, analysis, or interpretation of the data; or preparation, review, or approval of the manuscript for submission.

PATIENT CHARACTERISTICS AND EXPOSURE GROUPS

From the Danish Civil Personal Register, we obtained information on patients' age and sex. From the Danish Cardiac Arrest Registry, we obtained the date and year of cardiac arrest, the location of cardiac arrest (residential vs. public), bystander-witnessed and EMS-witnessed status, bystander CPR status, bystander defibrillation status, time interval (an estimate of the interval between the emergency call [based on time of emergency-call receipt, when available, and interview of bystanders who were on the scene] and first rhythm analysis by EMS), initial heart rhythm recorded by the EMS, and whether EMS personnel performed defibrillation. The presumed cause of cardiac arrest was determined on the basis of information from death certificates from the Danish Cause of Death Register and discharge diagnoses from the Danish National Patient Register, with the use of previously described methods.[7,10,22,23] To estimate the Charlson comorbidity index score (scores range from 0 to 37, with higher scores indicating more coexisting conditions), data on discharge diagnoses were collected from the Danish National Patient Register for the 10 years before the index cardiac arrest and data on prescription redemptions were collected from the Danish National Prescription Registry for the 180 days before the index cardiac arrest (Table S2 in the Supplementary Appendix).[23-25] For our analyses, we divided the survivors into four groups according to the nature of the bystander response: no bystander resuscitation, bystander CPR (but no bystander defibrillation), bystander defibrillation (regardless of bystander CPR status), and EMS-witnessed cardiac arrest.

OUTCOME VARIABLES AND MEASURES

Statistics Denmark is a government entity that has collected nursing home admission data since 1994, using validated methods to identify residents in all nursing home types and using street addresses and linkage to the Danish Civil Personal Registry to obtain personal address information.[26] All events of anoxic brain damage (*International Classification of Diseases, 10th Revision* [ICD-10] discharge diagnosis code, G93.1) between the index hospitalization and 1-year follow-up, including events between the index cardiac arrest and day 30, were recorded from the Danish National Patient Register (additional methods and data regarding anoxic brain damage are provided in the Supplementary Appendix).[23] Information on deaths was retrieved from the Danish Cause of Death Register and Civil Personal Registration Registry.[21,22] Using information from these data sources, we analyzed the following 1-year outcomes: anoxic brain damage or nursing home admission, death from any cause, and the composite end point of anoxic brain damage, nursing home admission, or death (whichever came first).

STATISTICAL ANALYSIS

Logistic regression was used to test differences between the group of patients who were surviving at 30 days and the group of patients who were not surviving at 30 days in relation to bystander interventions and calendar year. We used Poisson regression to test for a linear trend in the incidence of out-of-hospital cardiac arrest and the rate of 30-day survival according to calendar year. All other analyses were landmark analyses that included only the patients who survived to day 30 after an out-of-hospital cardiac arrest.[27]

Categorical variables were analyzed with the use of chi-square tests and are reported as percentages and frequencies; continuous variables were analyzed with the use of Kruskal–Wallis tests and are reported as medians and interquartile ranges. Linear calendar time trends were tested with the use of logistic regression for binary variables, linear regression for continuous variables, Fine–Gray regression for brain damage or nursing home admission, and Cox regression for death from any cause and the composite end point of brain damage, nursing home admission, or death. For categorical variables with more than two categories, time trends were tested by logistic regression for each category separately. For outcome analyses, only events that occurred within 1 year after the index cardiac arrest were analyzed.

Cox regression was used to assess associations between bystander interventions and outcome hazards, with adjustment for year of cardiac arrest, age, sex, Charlson comorbidity index score, cause of cardiac arrest, witnessed status, and time between recognition of cardiac arrest and EMS rhythm analysis. The absolute risks of brain damage or nursing home admission were obtained for the EMS-witnessed and bystander-intervention groups with the use of a stratified

Aalen–Johansen estimate (without further adjustment) and by combining a Cox cause-specific multiple regression model for the hazard of brain damage or nursing home admission with a Cox cause-specific multiple regression model for the hazard of the competing risk of death without brain damage or nursing home admission.[28] Absolute risks of brain damage or nursing home admission according to bystander intervention and EMS-witnessed status were reported together with all-cause mortality, both without further adjustment.

Sensitivity analyses of absolute risks were performed with adjustment for age, sex, and Charlson comorbidity index score, as well as in subsets of survivors with a presumed cardiac cause of cardiac arrest, survivors with witnessed cardiac arrest, and survivors who received defibrillation in the prehospital setting. The main analyses were based on data from patients for whom complete information on all variables was available. Sensitivity analyses were performed with the use of multiple imputation (additional details are provided in the Methods section in the Supplementary Appendix).[29] A two-sided P value of less than 0.05 was considered to indicate statistical significance. Data management and statistical analyses were performed with the use of SAS software, version 9.4 (SAS Institute), and R software.[30]

RESULTS

PATIENTS AND CHARACTERISTICS

During the period from 2001 through 2012 in Denmark, there were 42,089 patients who had an out-of-hospital cardiac arrest and for whom resuscitation was attempted. Among these patients, 34,459 were eligible for inclusion in our study, of whom 2855 (8.3%) were 30-day survivors (Fig. S1 in the Supplementary Appendix). Although the incidence of out-of-hospital cardiac arrest remained stable during this period (Fig. S2 in the Supplementary Appendix), the percentage of 30-day survivors increased from 3.9% to 12.4% (Table S3 in the Supplementary Appendix). Patients who received bystander interventions were more likely to be 30-day survivors than were those who did not receive bystander interventions (Table S3 in the Supplementary Appendix).

The characteristics of the 30-day survivors are shown in Table 1. Of the 153 survivors who received bystander defibrillation, 142 (92.8%) also received bystander CPR. The bystander-CPR and bystander-defibrillation groups had greater proportions of men, greater proportions of patients who had a witnessed cardiac arrest and a public location of cardiac arrest, and lower Charlson comorbidity index scores than did the group of patients who did not receive bystander resuscitation. The patients who had an EMS-witnessed cardiac arrest and the patients who did not receive bystander resuscitation were older and had higher Charlson comorbidity scores than the patients in the bystander-intervention groups. The patients in the bystander-CPR group had a shockable initial rhythm more often than did the patients in the no-bystander-resuscitation group or the bystander-defibrillation group. Although the EMS-witnessed group had the lowest likelihood of shockable rhythm (47.1%), EMS personnel eventually performed defibrillation in 75.0% of these patients. The likelihood of EMS defibrillation was significantly higher among survivors who received bystander CPR than among those who did not (Table 1). The above characteristics similarly applied to survivors of cardiac arrest of presumed cardiac causes (Table S4 in the Supplementary Appendix).

OUTCOMES AMONG 30-DAY SURVIVORS

Of the 2855 patients who were 30-day survivors of out-of-hospital cardiac arrest, 276 (9.7%) died during the 1-year follow-up period. Of these, 197 (71.4%) had a presumed cardiovascular cause of death. During the same follow-up period, 300 of the 30-day survivors (10.5%) had anoxic brain damage diagnosed or were admitted to a nursing home; among these, 59 died during the 1-year follow-up period, with a median time between brain damage or nursing home admission and death of 85 days (interquartile range, 28 to 173).

During the period from 2001 through 2012, the rates of bystander CPR and bystander defibrillation increased significantly among the 30-day survivors (Fig. 1). During this same interval, the proportion of 30-day survivors who had anoxic brain damage diagnosed or were admitted to a nursing home during 1 year of follow-up, as well as the proportion who died during 1 year of follow-up, decreased significantly (Fig. 2). The individual risks of brain damage and nursing home admission also decreased over time. No substantial differences were seen in risks of

Table 1. Characteristics of the Patients and Cardiac Arrests, According to Bystander Intervention and EMS-Witnessed Status among 30-Day Survivors.*

Characteristic	No Bystander Resuscitation (N=534)	Bystander CPR (N=1069)	Bystander Defibrillation (N=153)	EMS-Witnessed Cardiac Arrest (N=771)	Missing Status on Bystander Resuscitation (N=328)	P Value, All 30-Day Survivors of Cardiac Arrest (N=2855)	P Value, 30-Day Survivors of Cardiac Arrest Not Witnessed by EMS (N=2084)
Median age (IQR) — yr	64 (54–72)	61 (53–70)	62 (53–69)	64 (53–74)	60 (51–71)	<0.001	0.04
Male sex — no. (%)	378 (70.8)	850 (79.5)	137 (89.5)	574 (74.4)	262 (79.9)	<0.001	<0.001
Charlson comorbidity index score — no. (%)†						0.001‡	<0.001‡
0	339 (63.5)	764 (71.5)	110 (71.9)	511 (66.3)	215 (65.5)		
1	82 (15.4)	148 (13.8)	17 (11.1)	100 (13.0)	35 (10.7)		
≥2	113 (21.2)	157 (14.7)	26 (17.0)	160 (20.8)	78 (23.8)		
Public location of cardiac arrest — no./total no. (%)	159/458 (34.7)	568/973 (58.4)	114/139 (82.0)	316/632 (50.0)	151/257 (58.8)	<0.001	<0.001
Data missing — no. (%)	76 (14.2)	96 (9.0)	14 (9.2)	139 (18.0)	71 (21.6)		
Bystander-witnessed cardiac arrest — no./total no. (%)	409/531 (77.0)	946/1063 (89.0)	140/153 (91.5)	NA	150/168 (89.3)	NA	<0.001
Data missing — no. (%)	3 (0.6)	6 (0.6)	0	771 (100.0)	160 (48.8)		
Median time interval (IQR) — min§	7 (4–10)	9 (6–12)	12 (8–17)	NA	8 (6–10)	NA	0.21
Data missing — no. (%)	27 (5.1)	61 (5.7)	24 (15.7)	771 (100.0)	317 (96.6)		
Shockable initial rhythm — no./total no. (%)	361/517 (69.8)	898/1044 (86.0)	78/145 (53.8)	338/717 (47.1)	155/210 (73.8)	<0.001	<0.001
Data missing — no. (%)	17 (3.2)	25 (2.3)	8 (5.2)	54 (7.0)	118 (36.0)		
Defibrillation by EMS — no./total no. (%)	408/530 (77.0)	953/1063 (89.7)	75/151 (49.7)	538/717 (75.0)	11/40 (27.5)	<0.001	<0.001
Data missing — no. (%)	4 (0.7)	6 (0.6)	2 (1.3)	54 (7.0)	288 (87.8)		
Presumed cardiac cause of arrest — no./total no. (%)	468/518 (90.3)	980/1042 (94.0)	150/151 (99.3)	715/760 (94.1)	249/313 (79.6)	<0.001	<0.001
Data missing — no. (%)	16 (3.0)	27 (2.5)	2 (1.3)	11 (1.4)	15 (4.6)		

* CPR denotes cardiopulmonary resuscitation, EMS emergency medical services, IQR interquartile range, and NA not applicable.
† The Charlson comorbidity index score ranges from 0 to 37, with higher scores indicating more coexisting conditions; details are provided in Table S2 in the Supplementary Appendix.
‡ P value is for the trend across Charlson comorbidity index scores.
§ The time interval is an estimate of the duration between the emergency call (based on time of the emergency-call receipt, when available, and interviews of bystanders on the scene) and the first rhythm analysis by EMS personnel.

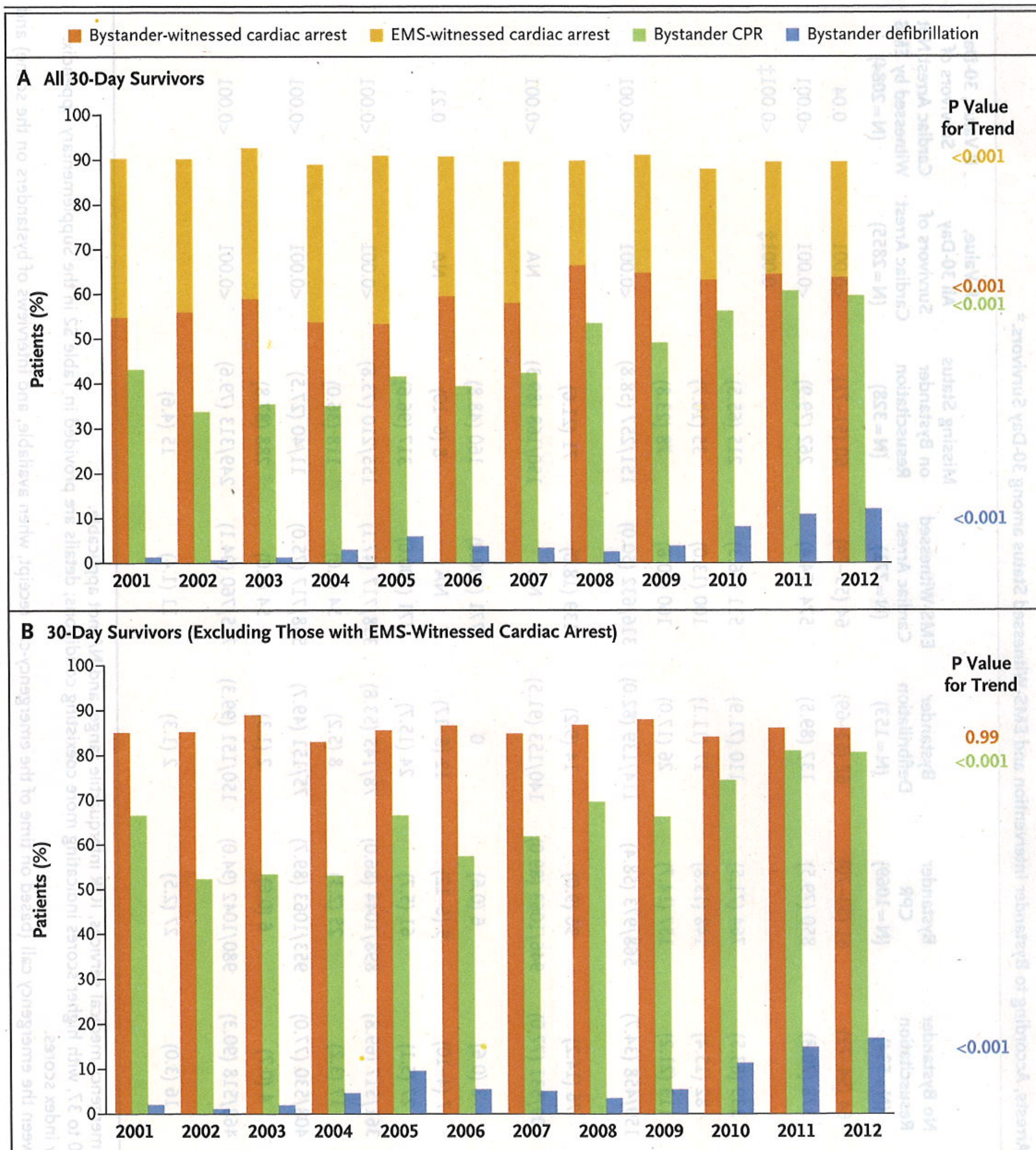

Figure 1. Rates of Bystander-Witnessed Status, Bystander Cardiopulmonary Resuscitation (CPR), and Bystander Defibrillation among 30-Day Survivors According to Calendar Year, 2001–2012.

The rate according to calendar year is shown for all 30-day survivors of cardiac arrest (Panel A, 2855 patients) and all 30-day survivors of cardiac arrest that was not witnessed by emergency medical services (EMS) personnel (Panel B, 2084 patients). Linear calendar time trends were tested by logistic regression. In Panel A, the P value for trend for bystander-witnessed cardiac arrest indicates a significant increase in bystander-witnessed cardiac arrests over time, whereas the P value for trend indicates a significant decrease in EMS-witnessed cardiac arrests over time; overall, the P value for trend for witnessed cardiac arrests (either by bystanders or EMS personnel) was not significant (P=0.34). For the analyses in both panels, 169 patients had missing witnessed status and were excluded from analyses of temporal changes in bystander-witnessed cardiac arrest and EMS-witnessed cardiac arrest (both combined and separately); 151 patients had missing status with regard to bystander CPR and were excluded from analyses of trends in bystander CPR; and 321 patients had missing status with regard to bystander defibrillation and were excluded from analyses of trends in bystander defibrillation.

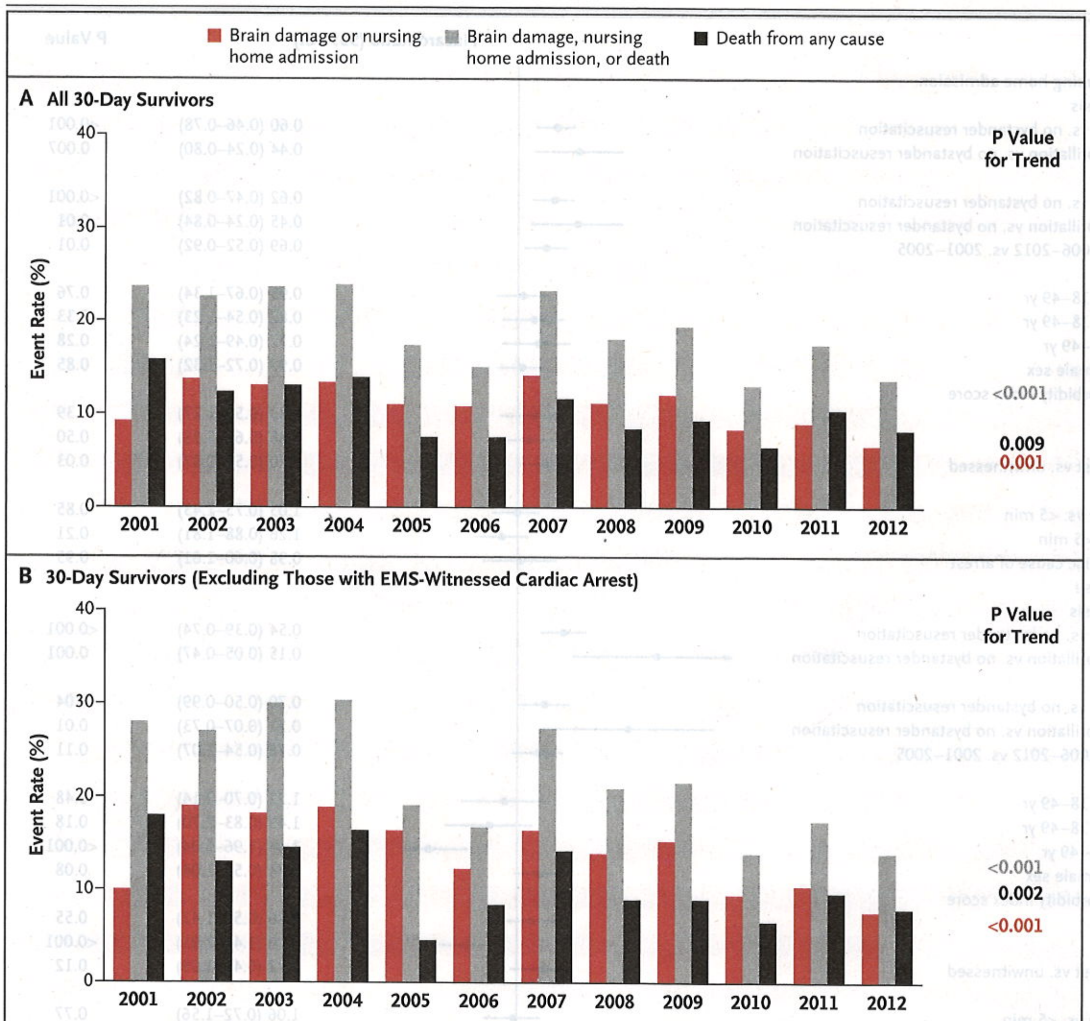

Figure 2. Outcomes at 1 Year among 30-Day Survivors According to Calendar Year.

One-year outcomes according to calendar year are shown for all 30-day survivors of cardiac arrest (Panel A, 2855 patients) and 30-day survivors of cardiac arrest that was not witnessed by EMS personnel (Panel B, 2084 patients). Linear calendar time trends were tested with the use of a Cox regression for the 1-year risk of death from any cause and the risk of the composite end point of brain damage, nursing home admission, or death; Fine–Gray regression was used to test time trends for the 1-year risk of brain damage or nursing home admission.

anoxic brain damage according to region. Additional details on temporal trends during the study period are provided in Tables S5 through S10, and details on regional differences are provided in the Results section in the Supplementary Appendix.

In adjusted analyses, bystander CPR and bystander defibrillation were both associated with a risk of anoxic brain damage or nursing home admission that was significantly lower than that associated with no bystander resuscitation (Fig. 3). In sensitivity analyses performed with the use of multiple imputation to account for missing data, the results were similar (Fig. S3 in the Supplementary Appendix). Similar findings were obtained when the risk of death from any cause and the risk of the composite end point of brain damage, nursing home admission, or death was examined (Fig. 3, and Fig. S3 in the Supplementary Appendix). Time-to-event curves for these outcomes are shown in Figure S4 in the Supplementary Appendix.

Factor	Hazard Ratio (95% CI)	P Value
Brain damage or nursing home admission		
Unadjusted analysis		
Bystander CPR vs. no bystander resuscitation	0.60 (0.46–0.78)	<0.001
Bystander defibrillation vs. no bystander resuscitation	0.44 (0.24–0.80)	0.007
Adjusted analysis		
Bystander CPR vs. no bystander resuscitation	0.62 (0.47–0.82)	<0.001
Bystander defibrillation vs. no bystander resuscitation	0.45 (0.24–0.84)	0.01
Year of arrest 2006–2012 vs. 2001–2005	0.69 (0.52–0.92)	0.01
Age		
50–64 yr vs. 18–49 yr	0.95 (0.67–1.34)	0.76
65–74 yr vs. 18–49 yr	0.82 (0.54–1.23)	0.33
≥75 yr vs. 18–49 yr	0.77 (0.49–1.24)	0.28
Male sex vs. female sex	0.97 (0.72–1.32)	0.85
Charlson comorbidity index score		
1 vs. 0	0.83 (0.55–1.27)	0.39
≥2 vs. 0	0.88 (0.61–1.28)	0.50
Witnessed arrest vs. unwitnessed	0.70 (0.50–0.97)	0.03
Time interval		
5 to <12 min vs. <5 min	1.03 (0.75–1.43)	0.85
≥12 min vs. <5 min	1.26 (0.88–1.81)	0.21
Presumed cardiac cause of arrest	0.98 (0.60–1.61)	0.95
Death from any cause		
Unadjusted analysis		
Bystander CPR vs. no bystander resuscitation	0.54 (0.39–0.74)	<0.001
Bystander defibrillation vs. no bystander resuscitation	0.15 (0.05–0.47)	0.001
Adjusted analysis		
Bystander CPR vs. no bystander resuscitation	0.70 (0.50–0.99)	0.04
Bystander defibrillation vs. no bystander resuscitation	0.22 (0.07–0.73)	0.01
Year of arrest 2006–2012 vs. 2001–2005	0.76 (0.54–1.07)	0.11
Age		
50–64 yr vs. 18–49 yr	1.22 (0.70–2.14)	0.48
65–74 yr vs. 18–49 yr	1.49 (0.83–2.70)	0.18
≥75 yr vs. 18–49 yr	3.44 (1.96–6.04)	<0.001
Male sex vs. female sex	0.74 (0.52–1.04)	0.08
Charlson comorbidity index score		
1 vs. 0	0.86 (0.52–1.42)	0.55
≥2 vs. 0	2.06 (1.44–2.95)	<0.001
Witnessed arrest vs. unwitnessed	0.72 (0.48–1.09)	0.12
Time interval		
5 to <12 min vs. <5 min	1.06 (0.72–1.56)	0.77
≥12 min vs. <5 min	1.05 (0.67–1.64)	0.83
Presumed cardiac cause of arrest	0.48 (0.30–0.77)	0.002
Brain damage, nursing home admission, or death		
Unadjusted analysis		
Bystander CPR vs. no bystander resuscitation	0.58 (0.47–0.72)	<0.001
Bystander defibrillation vs. no bystander resuscitation	0.36 (0.21–0.62)	<0.001
Adjusted analysis		
Bystander CPR vs. no bystander resuscitation	0.67 (0.53–0.84)	<0.001
Bystander defibrillation vs. no bystander resuscitation	0.45 (0.26–0.79)	0.005
Year of arrest 2006–2012 vs. 2001–2005	0.69 (0.55–0.87)	0.002
Age		
50–64 yr vs. 18–49 yr	0.91 (0.67–1.25)	0.56
65–74 yr vs. 18–49 yr	0.88 (0.62–1.25)	0.48
≥75 yr vs. 18–49 yr	1.38 (0.97–1.97)	0.07
Male sex vs. female sex	0.84 (0.66–1.07)	0.15
Charlson comorbidity index score		
1 vs. 0	0.88 (0.63–1.24)	0.47
≥2 vs. 0	1.29 (0.98–1.69)	0.07
Witnessed arrest vs. unwitnessed	0.70 (0.53–0.93)	0.01
Time interval		
5 to <12 min vs. <5 min	1.08 (0.83–1.41)	0.57
≥12 min vs. <5 min	1.15 (0.85–1.56)	0.36
Presumed cardiac cause of arrest	0.71 (0.50–1.01)	0.06

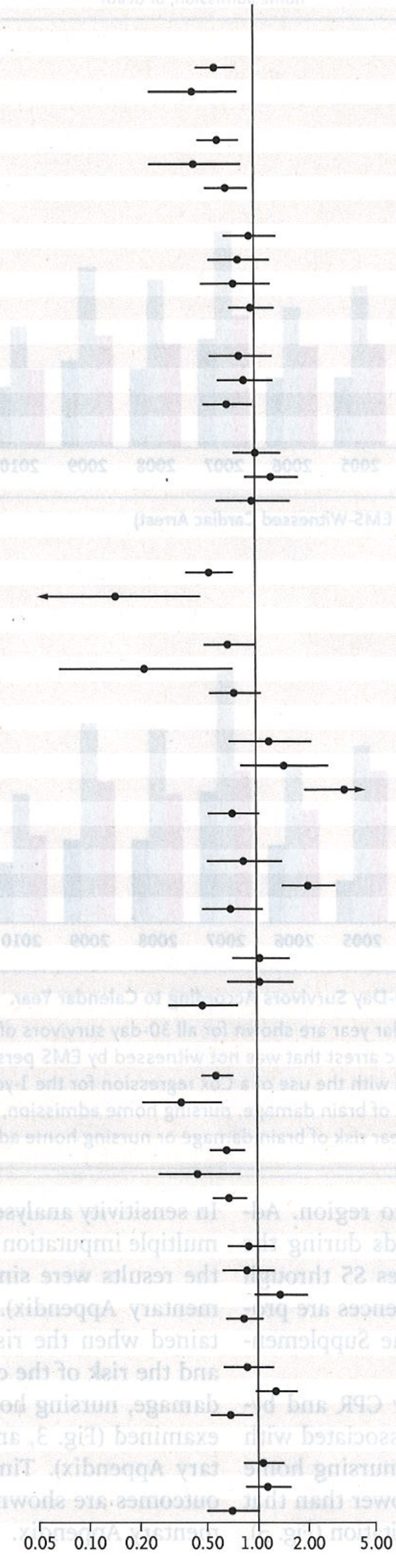

Figure 3 (facing page). Association between Bystander Interventions and 1-Year Outcomes among 30-Day Survivors of Cardiac Arrest Not Witnessed by EMS Personnel.

The results of cause-specific Cox regression are shown as hazard ratios for differences in bystander interventions with regard to the composite end point of anoxic brain damage or nursing home admission; the results of Cox regression are also shown as hazard ratios for differences in bystander interventions for the outcomes of death from any cause and composite end point of brain damage, nursing home admission, or death. Shown are results from univariate analyses and multivariate analyses that were adjusted for age, sex, Charlson comorbidity index score (scores range from 0 to 37, with higher scores indicating more coexisting conditions; details are provided in Table S2 in the Supplementary Appendix), year of cardiac arrest, witnessed status, time interval (duration from the emergency call [based on time of the emergency-call receipt, when available, and interview of bystanders on the scene] to first rhythm analysis by EMS), and presumed cause of cardiac arrest. Data for 1595 of 2084 patients with cardiac arrest that was not witnessed by EMS personnel are included; patients with missing status for bystander CPR or bystander defibrillation (328 patients) and with missing status for other variables, including witnessed status, time interval, and presumed cause of cardiac arrest (161 patients), are not included in the analyses. CI denotes confidence interval.

The absolute 1-year risk of anoxic brain damage or nursing home admission was lowest in the group with EMS-witnessed cardiac arrest (3.7%; 95% confidence interval [CI], 2.5 to 4.9) (Fig. 4, and Table S11 in the Supplementary Appendix). However, the lowest absolute 1-year risk of death was seen in the bystander-defibrillation group (2.0%; 95% CI, 0.0 to 4.2). The no-bystander-resuscitation group had the highest risk of brain damage or nursing home admission (18.6%; 95% CI, 16.0 to 22.2) and death from any cause (15.5%; 95% CI, 12.5 to 18.6). The results were consistent when multiple imputation methods were applied; across groups defined according to age, sex, and Charlson comorbidity index score; among survivors with cardiac arrest of presumed cardiac causes and witnessed cardiac arrest; and among survivors who received defibrillation in a prehospital setting. Additional details, as well as results for outcomes stratified according to the initial EMS-assessed heart rhythm, are provided in Figures S5 through S12 in the Supplementary Appendix.

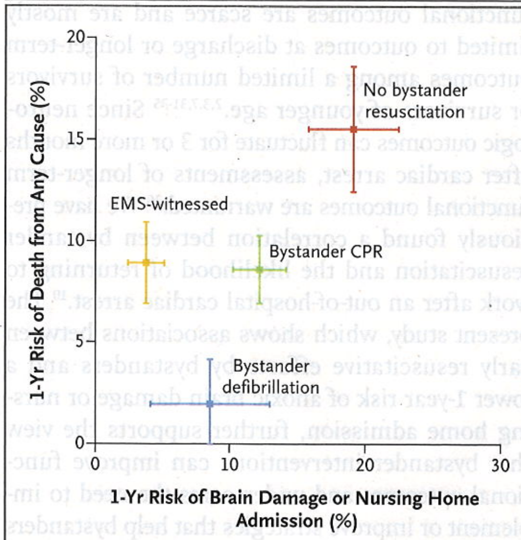

Figure 4. Absolute Risk of Anoxic Brain Damage or Nursing Home Admission and Death from Any Cause at 1 Year of Follow-up According to EMS-Witnessed and Bystander-Intervention Status.

Shown are the 1-year absolute risk of anoxic brain damage or nursing home admission and the 1-year absolute risk of death from any cause in relation to EMS-witnessed and bystander-intervention status. Data for 2527 of 2855 patients are included; those with missing status for bystander CPR or bystander defibrillation (328 patients) are not included in the analyses. Squares indicate point estimates (absolute risks), and I bars 95% confidence intervals.

DISCUSSION

This nationwide study involving 2855 patients who were 30-day survivors of out-of-hospital cardiac arrest during the period from 2001 through 2012 had two key findings. First, the risk of anoxic brain damage or nursing home admission at 1 year and the risk of death from any cause at 1 year were significantly lower among 30-day survivors who received bystander CPR or defibrillation than among survivors who did not receive bystander resuscitation. Second, concurrent with significant increases in the rates of bystander CPR and defibrillation, the risk of anoxic brain damage or nursing home admission and the risk of death from any cause at 1 year decreased markedly during this period.

Although it is well established that bystander interventions increase survival rates, reports of associations between bystander interventions and functional outcomes are scarce and are mostly limited to outcomes at discharge or longer-term outcomes among a limited number of survivors or survivors of younger age.[2,3,7,31-35] Since neurologic outcomes can fluctuate for 3 or more months after cardiac arrest, assessments of longer-term functional outcomes are warranted.[36] We have previously found a correlation between bystander resuscitation and the likelihood of returning to work after an out-of-hospital cardiac arrest.[10] The present study, which shows associations between early resuscitative efforts by bystanders and a lower 1-year risk of anoxic brain damage or nursing home admission, further supports the view that bystander interventions can improve functional outcomes and underscores the need to implement or improve strategies that help bystanders initiate CPR and strategies that facilitate public access to automated external defibrillators.

Survivors of EMS-witnessed cardiac arrest constitute a distinct group, since in these cases EMS personnel were on the scene before the patient collapsed. In most cases, these patients did not have a sudden onset of cardiac arrest but instead had cardiac arrest during gradual worsening of an acute medical condition for which EMS had already been activated. EMS-witnessed cardiac arrests are probably managed with higher-quality CPR and more rapid and effective use of defibrillators than are cardiac arrests with bystander intervention, which may explain why the patients with EMS-witnessed cardiac arrest had the lowest risk of brain damage or nursing home admission. However, all-cause mortality was significantly higher among 30-day survivors who had EMS-witnessed cardiac arrest than among those who received bystander defibrillation, which may be explained by the higher age and comorbidity scores of survivors who had EMS-witnessed cardiac arrests.

The rates of both bystander CPR and bystander defibrillation significantly increased among 30-day survivors from 2001 through 2012. Such increases are probably related to the multiple nationwide initiatives that have been taken in Denmark, including widespread mandatory and voluntary CPR training; widespread dissemination of automated external defibrillators; the introduction of health care professionals at emergency dispatch centers, facilitating dispatcher-assisted CPR; and the formation and linkage of an automated external defibrillator registry to the dispatch centers, enabling health care professionals to guide bystanders to the nearest automated external defibrillators (bystanders themselves can also locate the nearest automated external defibrillator with the use of a smartphone application).[7,37] Altogether, the changes in functional outcomes that were observed after these initiatives were implemented suggest that systematic national efforts to improve cardiac-arrest management may result in improvements not only in survival but also in functionally intact survival.

This study had some limitations. First, because of the observational nature of our study, factors associated with both bystander interventions and outcomes could have influenced our findings. However, when the year of cardiac arrest and other important confounders were accounted for in multiple regression analyses, bystander interventions remained associated with a significantly lower risk of brain damage or nursing home admission. Although we did not have information on the duration of cardiac arrest, we included witnessed status in our models in an attempt to adjust for this potential confounder under the assumption that patients with a witnessed cardiac arrest have a shorter duration of arrest than do those with an unwitnessed cardiac arrest. Second, some patients had missing data. No substantial differences were found between results from analyses that included patients with complete data observations and results based on the entire study population in analyses that were conducted with the use of multiple imputation. Therefore, we consider missing data to be unlikely to have influenced our main findings. Third, detailed information on functional status related to neurologic disability (such as the modified Rankin scale) or on quality of life was not available. Nevertheless, the outcome of anoxic brain damage or nursing home admission is a measure that is likely to reflect substantial neurologic impairment that has been correlated with low quality of life.[14-16] Finally, individual clinicians' thresholds for diagnosing anoxic brain damage cannot be examined with the use of registry data. However, no substantial differences were seen in the proportions of patients who had anoxic brain damage diagnosed across the five health care regions in Denmark.

In conclusion, we examined outcomes among 30-day survivors of out-of-hospital cardiac arrest. The risk of anoxic brain damage or nursing home admission at 1 year and the risk of death from any cause at 1 year were substantially lower among survivors who received bystander CPR or bystander defibrillation than among those who received no bystander resuscitation.

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