ORIGINAL ARTICLE

Trends in Survival after In-Hospital Cardiac Arrest

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ABSTRACT

BACKGROUND

Despite advances in resuscitation care in recent years, it is not clear whether survival and neurologic function after in-hospital cardiac arrest have improved over time.

METHODS

We identified all adults who had an in-hospital cardiac arrest at 374 hospitals in the Get with the Guidelines–Resuscitation registry between 2000 and 2009. Using multivariable regression, we examined temporal trends in risk-adjusted rates of survival to discharge. Additional analyses explored whether trends were due to improved survival during acute resuscitation or postresuscitation care and whether they occurred at the expense of greater neurologic disability in survivors.

RESULTS

Among 84,625 hospitalized patients with cardiac arrest, 79.3% had an initial rhythm of asystole or pulseless electrical activity, and 20.7% had ventricular fibrillation or pulseless ventricular tachycardia. The proportion of cardiac arrests due to asystole or pulseless electrical activity increased over time (P<0.001 for trend). Risk-adjusted rates of survival to discharge increased from 13.7% in 2000 to 22.3% in 2009 (adjusted rate ratio per year, 1.04; 95% confidence interval [CI], 1.03 to 1.06; P<0.001 for trend). Survival improvement was similar in the two rhythm groups and was due to improvement in both acute resuscitation survival and postresuscitation survival. Rates of clinically significant neurologic disability among survivors decreased over time, with a risk-adjusted rate of 32.9% in 2000 and 28.1% in 2009 (adjusted rate ratio per year, 0.98; 95% CI, 0.97 to 1.00; P=0.02 for trend).

CONCLUSIONS

Both survival and neurologic outcomes after in-hospital cardiac arrest have improved during the past decade at hospitals participating in a large national quality-improvement registry. (Funded by the American Heart Association.)

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Data from a number of emergency medical services systems suggest that advances in resuscitation care during the past decade have led to higher rates of survival among patients with out-of-hospital cardiac arrest.[1-4] In the in-hospital setting, quality-improvement efforts have included the use of routine mock cardiac arrests, postresuscitation debriefing, defibrillation by nonmedical personnel, and participation in quality-improvement registries, such as the Get with the Guidelines (GWTG)–Resuscitation registry (formerly the National Registry of Cardiopulmonary Resuscitation).[5-9] Whether overall survival among patients with in-hospital cardiac arrest has improved with these efforts remains unknown.

To date, only one study has examined temporal trends in survival after in-hospital cardiac arrest. This study showed no significant change in survival to discharge among hospitalized Medicare patients undergoing cardiopulmonary resuscitation (CPR) from 1992 through 2005.[10] Although large and nationally representative, this study used data from administrative claims and may have included patients without cardiac arrest (e.g., patients undergoing CPR for bradycardia) or excluded patients for whom a procedure code for CPR was not submitted. Moreover, information on the initial cardiac-arrest rhythm, which has likely changed over time, was not available. This is important because advances in the management of acute myocardial infarction and heart failure may have led to a decline in the proportion of in-hospital cardiac arrests in which the initial rhythm is ventricular fibrillation or pulseless ventricular tachycardia. Because these rhythms are associated with better survival[9,11,12] than asystole or pulseless electrical activity, it is possible that rhythm-specific survival in that study improved, even though overall survival did not change significantly.

Therefore, we examined temporal trends in rates of survival to hospital discharge within a large, national quality-improvement registry of in-hospital cardiac arrests. Because improved survival among these patients may occur at the expense of worsened neurologic function, we also explored temporal trends in rates of neurologic disability among survivors at discharge.

METHODS

DATA SOURCE

The GWTG–Resuscitation registry is a large, prospective, hospital-based, clinical registry of patients with in-hospital cardiac arrests in the United States. The design of the registry has been previously described in detail.[9] Briefly, all hospitalized patients with a confirmed cardiac arrest (defined as the lack of a palpable central pulse, apnea, and unresponsiveness), without do-not-resuscitate (DNR) orders, and who have received CPR are identified and enrolled by specially trained personnel. To ensure that all cases in a hospital are captured, multiple case-finding approaches are used, including centralized collection of cardiac-arrest flow sheets, review of hospital paging-system logs, and routine checks of code carts (carts stocked with emergency medications and equipment), pharmacy tracer drug records, and hospital billing charges for use of resuscitation medications.[13] The registry uses standardized Utstein-style definitions for clinical variables and outcomes.[14,15] Data completeness and accuracy is ensured by rigorous training and certification of hospital staff, use of standardized software with internal data checks, and a periodic re-abstraction process, in which a random audit has revealed a mean error rate of 2.4%.[9]

This study was approved by the institutional review board at the University of Iowa. The requirement for informed consent was waived. The first author vouches for the integrity of the data and accuracy of the results. All analyses were prespecified and adhered to the study protocol. Although the American Heart Association oversees the GWTG–Resuscitation registry, it had no role in the study design, data analysis or interpretation, or manuscript preparation.

STUDY POPULATION

We identified 113,514 adults at 553 hospitals participating in the GWTG–Resuscitation registry who were 18 years of age or older with an index cardiac-arrest event from January 1, 2000, through November 19, 2009 (Fig. 1). For patients with multiple cardiac arrests, only the first episode was included. We restricted our sample to patients with cardiac arrests occurring in an intensive care unit or inpatient ward and excluded 24,377 patients with arrests in operating rooms, procedural suites, or emergency departments, because patients who have cardiac arrests in these settings have distinct clinical circumstances and outcomes. Because we were interested in examining trends in survival over time, we also excluded 4292 patients at 179 hospitals with fewer than 3 years of data submission or low case volumes (fewer than 5 cardiac arrests

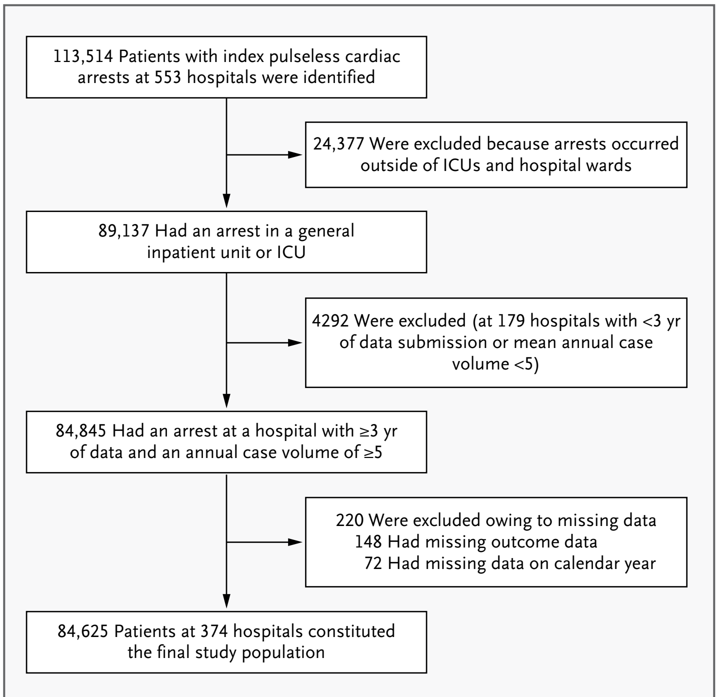

Figure 1. Study Cohort.
ICU denotes intensive care unit.

per year). Finally, we excluded patients with missing data on survival (148 patients) and calendar year (72 patients). Our final sample comprised 84,625 patients from 374 hospitals (for hospital characteristics, see Table S1 in the Supplementary Appendix, available with the full text of this article at NEJM.org).

STUDY OUTCOMES

The primary outcome was survival to discharge. All analyses are reported for the overall cohort and separately according to the initial rhythm. To better understand which specific phase of resuscitation care may have led to improvement in survival, we separately examined rates of acute resuscitation survival (defined as the return of spontaneous circulation for at least 20 contiguous minutes at any time after the initial pulseless arrest) and post-resuscitation survival (defined as survival to hospital discharge among patients who survived the acute resuscitation). We also examined temporal trends in time to defibrillation in patients with ventricular fibrillation or pulseless ventricular tachycardia.[16]

To confirm that any temporal trend in survival was clinically important, we also examined rates of neurologic disability among survivors. This was assessed with the use of the cerebral-performance category (CPC) scores.[17] A CPC score of 1 denotes mild or no neurologic disability, 2 moderate neurologic disability, 3 severe neurologic disability, 4 coma or vegetative state, and 5 brain death. We examined temporal trends for clinically significant neurologic disability (CPC score at discharge, >1) and severe neurologic disability (CPC score at discharge, >2).[16,18]

STATISTICAL ANALYSIS

To evaluate changes in baseline characteristics by calendar year, we used the Mantel–Haenszel test of trend for categorical variables and linear regression for continuous variables. To assess whether survival to discharge had improved over time, multivariable regression models using generalized-estimation equations were constructed for the overall cohort and according to initial rhythm. These models accounted for clustering of patients within hospitals. Because survival exceeded 10%, we used Zou's method to directly estimate rate ratios instead of odds ratios by specifying a Poisson distribution and including a robust variance estimate in our models.[19,20] Our independent variable, calendar year, was included as a categorical variable, with 2000 as the reference year. We multiplied the adjusted rate ratio for each year (2001 through 2009) by the observed survival rate for the reference year to obtain yearly risk-adjusted survival rates for the study period. These rates represent the estimated survival for each year if the patient case mix were identical to that in the reference year. We also evaluated calendar year as a continuous variable to obtain adjusted rate ratios for year-to-year survival trends.

In our models, we adjusted for age, sex, race, coexisting conditions, therapeutic interventions in place at the time of cardiac arrest, characteristics of the cardiac arrest, and select hospital characteristics. A full list of the variables used in the multivariable models is provided in Table S2 in the Supplementary Appendix. To confirm that any survival trends were independent of the duration of hospital participation in the registry, we adjusted for the number of years of hospital participation for each arrest. We also examined whether survival trends differed by age group (≥65 years vs. <65 years), race, and sex by including an interaction term with calendar year in the model. Last, to exclude the possibility that our findings were due to enrollment of better-performing hospitals over time, we performed these analyses only for patients at hospitals with at least 8 years of registry participation.

Data were complete for all covariates and outcomes, except race (6.6% missing), CPC score at admission (14.6% missing), time of cardiac arrest (0.9% missing), hospital variables (4.5% missing), and CPC score at discharge (14.0% missing). Missing patient-level covariates were assumed to be missing at random and were imputed with the use of multiple imputation.[21] Results with and without imputation were not meaningfully different, so only the former are presented. Imputation was not performed for the outcome of CPC score at discharge.

All statistical analyses were conducted with the use of SAS software, version 9.1.3 (SAS Institute), IVEware (University of Michigan), or R software, version 2.6.0 (Free Software Foundation). All hypothesis tests were two-sided, with a significance level of 0.05.

RESULTS

PATIENT CHARACTERISTICS

Among 84,625 patients, the initial cardiac-arrest rhythm was asystole or pulseless electrical activity in 67,135 (79.3%) and ventricular fibrillation or pulseless ventricular tachycardia in 17,490 (20.7%). During the study period, the proportion of cardiac arrests due to asystole or pulseless electrical activity increased from 68.7% in 2000 to 82.4% in 2009 (P<0.001 for trend) (Fig. S1 in the Supplementary Appendix). Table 1 shows temporal trends in patient characteristics, grouped into three time periods. Although there was a calendar-year trend for younger age, less heart disease, and less baseline neurologic disability, the prevalence of septicemia, use of mechanical ventilation, and use of intravenous vasopressors before the arrest event increased over time (P<0.001 for trend for all comparisons).

SURVIVAL TO DISCHARGE

The overall rate of survival to discharge was 17.0% (14,357 of 84,625 patients). There was a significant trend toward increased survival during the study period for all study patients as well as for both rhythm groups (i.e., those with an initial rhythm of asystole or pulseless electrical activity and those with an initial rhythm of ventricular fibrillation or pulseless ventricular tachycardia) (Fig. 2, and Table S3 in the Supplementary Appendix). After adjustment for temporal trends in patient and hospital characteristics, overall survival increased from 13.7% in 2000 to 22.3% in 2009 (adjusted rate ratio per year, 1.04; 95% confidence interval [CI], 1.03 to 1.06; P<0.001 for trend) (Table 2). Full model results are available in Table S4 in the Supplementary Appendix. The temporal trends in survival were consistent in the two rhythm groups (Table S5 in the Supplementary Appendix) and were similar according to age group (≥65 years vs. <65 years), race (black vs. white), and sex (male vs. female) (P>0.10 for all interactions). Our findings were unchanged when we restricted the analyses to the 85 hospitals (33,464 patients) that participated in the GWTG–Resuscitation registry for at least 8 years (Table S6 in the Supplementary Appendix).

SECONDARY OUTCOMES

Rates of acute resuscitation survival also improved substantially in the overall cohort, with a risk-adjusted rate of 42.7% in 2000 and 54.1% in 2009 (adjusted rate ratio per year, 1.03; 95% CI, 1.02 to 1.04; P<0.001 for trend) (Table 2). This trend was also significant for both rhythm groups (Table S5 in the Supplementary Appendix). Temporal improvement in postresuscitation survival was somewhat smaller (Table 2, and Table S5 in the Supplementary Appendix). In patients with ventricular fibrillation or pulseless ventricular tachycardia, there was no significant change in time to defibrillation (Fig. S2 in the Supplementary Appendix).

Although rates of survival to discharge increased, rates of clinically significant neurologic disability (CPC score at discharge, >1) among survivors decreased over time in the overall cohort (risk-adjusted rate, 32.9% in 2000 and 28.1% in 2009; adjusted rate ratio per year, 0.98; 95% CI, 0.97 to 1.00; P=0.02 for trend) (Table 2) and in patients with ventricular fibrillation or pulseless ventricular tachycardia (Table S5 in the Supplementary Appendix). Rates of severe neurologic disability (CPC score at discharge, >2), however, did not change significantly over time (Table 2, and Table S5 in the Supplementary Appendix).

DISCUSSION

In our study of patients at hospitals participating in a national quality-improvement registry, we found that survival after in-hospital cardiac arrest improved substantially between 2000 and 2009. These gains have been accompanied by a

Table 1. Trends in Baseline Characteristics in Patients with an In-Hospital Cardiac Arrest.*

Characteristic	Year Group			P Value for Trend
	2000–2003 (N=23,633)	2004–2006 (N=32,603)	2007–2009 (N=28,389)	
Demographic characteristics				
Age	67.3±15.4	66.5±15.6	65.9±15.8	<0.001
Male sex — no. (%)	13,582 (57.5)	19,050 (58.4)	16,546 (58.3)	0.07
Black race — no./total no. (%)†	4,723/21,694 (21.8)	6,581/30,726 (21.4)	6,048/26,614 (22.7)	<0.001
Characteristics of cardiac arrest				
Initial cardiac-arrest rhythm — no. (%)				<0.001
Asystole	9,423 (39.9)	12,576 (38.6)	9,915 (34.9)	
Pulseless electrical activity	8,663 (36.7)	13,343 (40.9)	13,215 (46.5)	
Ventricular fibrillation	3,999 (16.9)	3,878 (11.9)	2,952 (10.4)	
Pulseless ventricular tachycardia	1,548 (6.6)	2,806 (8.6)	2,307 (8.1)	
Hospital location of arrest — no. (%)				<0.001
Intensive care unit	13,189 (55.8)	18,852 (57.8)	16,859 (59.4)	
Monitored unit	4,735 (20.0)	7,269 (22.3)	7,160 (25.2)	
Nonmonitored unit	5,709 (24.2)	6,482 (19.9)	4,370 (15.4)	
Arrest at night (11 p.m. to 7 a.m.) — no./total no. (%)	8,369/23,336 (35.9)	11,410/32,323 (35.3)	9,880/28,168 (35.1)	0.09
Arrest on weekend — no. (%)	7,570 (32.0)	10,470 (32.1)	9,049 (31.9)	0.12
Hospital-wide response activated — no. (%)	21,013 (88.9)	28,182 (86.4)	23,559 (83.0)	<0.001
Assessed with AED — no. (%)	1,094 (4.6)	3,545 (10.9)	5,169 (18.2)	<0.001
Amiodarone use in resuscitation — no. (%)	3,290 (13.9)	5,275 (16.2)	5,169 (18.2)	<0.001
Preexisting conditions				
Heart failure, this admission — no. (%)	4,919 (20.8)	6,702 (20.6)	5,113 (18.0)	<0.001
Previous heart failure — no. (%)	6,131 (25.9)	7,305 (22.4)	5,743 (20.2)	<0.001
Myocardial infarction, this admission — no. (%)	4,602 (19.5)	5,792 (17.8)	4,263 (15.0)	<0.001
Previous myocardial infarction — no. (%)	5,000 (21.2)	5,771 (17.7)	4,261 (15.0)	<0.001
Arrhythmia — no. (%)	7,850 (33.2)	12,052 (37.0)	8,887 (31.3)	<0.001
Hypotension — no. (%)	6,353 (26.9)	10,065 (30.9)	7,566 (26.7)	<0.001
Respiratory insufficiency — no. (%)	9,799 (41.5)	14,930 (45.8)	11,943 (42.1)	<0.001
Renal insufficiency — no. (%)	8,076 (34.2)	11,999 (36.8)	10,062 (35.4)	<0.001
Hepatic insufficiency — no. (%)	1,771 (7.5)	2,947 (9.0)	2,342 (8.2)	<0.001
Metabolic or electrolyte abnormality — no. (%)	4,601 (19.5)	6,646 (20.4)	4,367 (15.4)	<0.001
Diabetes mellitus — no. (%)	7,183 (30.4)	10,550 (32.4)	8,944 (31.5)	<0.001
Baseline depression in CNS function — no. (%)	3,216 (13.6)	4,706 (14.4)	3,347 (11.8)	<0.001
Acute stroke — no. (%)	1,037 (4.4)	1,454 (4.5)	1,155 (4.1)	0.15
CPC category before arrest — no./total no. (%)‡				<0.001
1	9,769/19,224 (50.8)	14,524/29,190 (49.8)	12,902/23,815 (54.2)	
2	5,882/19,224 (30.6)	9,047/29,190 (31.0)	6,496/23,815 (27.3)	
3	2,531/19,224 (13.2)	4,090/29,190 (14.0)	3,004/23,815 (12.6)	
4 or 5	1,042/19,224 (5.4)	1,529/29,190 (5.2)	1,413/23,815 (5.9)	

Table 1. (Continued.)

Characteristic	Year Group			P Value for Trend
	2000–2003 (N=23,633)	2004–2006 (N=32,603)	2007–2009 (N=28,389)	
Pneumonia — no. (%)	3,591 (15.2)	5,015 (15.4)	4,239 (14.9)	<0.001
Septicemia — no. (%)	3,367 (14.2)	6,037 (18.5)	5,363 (18.9)	<0.001
Major trauma — no. (%)	693 (2.9)	1,164 (3.6)	1,121 (3.9)	<0.001
Metastatic cancer — no. (%)	2,909 (12.3)	4,529 (13.9)	3,846 (13.5)	<0.001
Interventions in place before the arrest — no. (%)				
Mechanical ventilation	6,388 (27.0)	10,300 (31.6)	9,702 (34.2)	<0.001
Intravenous vasopressor medication	6,804 (28.8)	9,175 (28.1)	9,060 (31.9)	<0.001
Intravenous antiarrhythmic therapy	1,435 (6.1)	1,944 (6.0)	1,953 (6.9)	<0.001
Dialysis	897 (3.8)	1,421 (4.4)	1,118 (3.9)	<0.001
Intraaortic balloon pump	394 (1.7)	534 (1.6)	449 (1.6)	0.65
Pulmonary-artery catheter	1,346 (5.7)	1,534 (4.7)	869 (3.1)	<0.001
Hospital characteristics — no./total no. (%)				
Geographic region				<0.001
Northeast	2,536/21,661 (11.7)	4,616/31,403 (14.7)	3,531/27,748 (12.7)	
Southeast	6,604/21,661 (30.5)	8,549/31,403 (27.2)	7,828/27,748 (28.2)	
Midwest	5,782/21,661 (26.7)	7,694/31,403 (24.5)	6,186/27,748 (22.3)	
Southwest	3,524/21,661 (16.3)	5,022/31,403 (16.0)	5,874/27,748 (21.2)	
West	3,215/21,661 (14.8)	5,522/31,403 (17.6)	4,329/27,748 (15.6)	
Location				<0.001
Urban	20,320/21,661 (93.8)	29,722/31,403 (94.6)	26,387/27,748 (95.1)	
Rural	1,341/21,661 (6.2)	1,681/31,403 (5.4)	1,361/27,748 (4.9)	
Ownership				<0.001
Private	1,768/21,661 (8.2)	3,213/31,403 (10.2)	3,547/27,748 (12.8)	
Government	3,493/21,661 (16.1)	5,205/31,403 (16.6)	4,919/27,748 (17.7)	
Nonprofit	16,400/21,661 (75.7)	22,985/31,403 (73.2)	19,282/27,748 (69.5)	
Size				<0.001
<250 beds	5,074/22,063 (23.0)	6,649/31,829 (20.9)	4,916/28,086 (17.5)	
250–499 beds	8,546/22,063 (38.7)	13,573/31,829 (42.6)	12,250/28,086 (43.6)	
≥500 beds	8,443/22,063 (38.3)	11,607/31,829 (36.5)	10,920/28,086 (38.9)	
Type of hospital				<0.001
Academic with fellowship program (major)	6,278/22,063 (28.5)	10,794/31,829 (33.9)	11,241/28,086 (40.0)	
Academic with residency program (minor)	7,485/22,063 (33.9)	10,674/31,829 (33.5)	8,445/28,086 (30.1)	
Nonteaching	8,300/22,063 (37.6)	10,361/31,829 (32.6)	8,400/28,086 (29.9)	

* For illustrative purposes, trends in baseline characteristics are presented as three time periods (2000–2003, 2004–2006, and 2007–2009). The P value for trend is for temporal changes in these characteristics by calendar year. Plus–minus values are means ±SD. AED denotes automated external defibrillator, and CNS central nervous system,

† Race was self-reported.

‡ A cerebral-performance category (CPC) score of 1 denotes mild to no neurologic disability, 2 moderate neurologic disability, 3 severe neurologic disability, 4 coma or vegetative state, and 5 brain death.

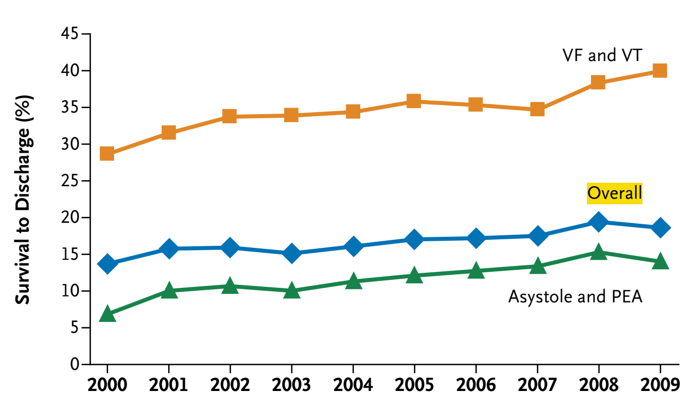

Figure 2. Unadjusted Rates of Survival to Hospital Discharge by Calendar Year.
Observed (crude) rates for survival to discharge are shown for the overall cohort and separately for shockable cardiac-arrest rhythms (ventricular fibrillation [VF] and pulseless ventricular tachycardia [VT]) and nonshockable cardiac-arrest rhythms (asystole and pulseless electrical activity [PEA]). $P<0.001$ for trend for each survival curve.

decrease in the rate of clinically significant neurologic disability among survivors. Using a conservative estimate of 200,000 in-hospital cardiac arrests annually in the United States,[22] we estimate that an additional 17,200 patients survived to hospital discharge in 2009 as compared with 2000 (on the basis of an 8.6% absolute improvement in risk-adjusted survival during this period). We also estimate that more than 13,000 cases of clinically significant neurologic disability were avoided.

The unadjusted survival rate of 17.0% in our study was lower than the 18.3% survival rate found in a study involving Medicare patients.[10] This difference is due in large part to the fact that we excluded cardiac arrests in the emergency room and procedural areas, where survival rates are known to be higher.[23,24] Although the Medicare study did not detect survival trends,[10] several factors probably explain our different findings. Because that study used procedure codes for CPR to identify patients with cardiac arrest, it is possible that some patients who received CPR for bradycardia (and not cardiac arrest) were included. Moreover, the Medicare study was unable to adjust for initial cardiac-arrest rhythm, which we found had changed over time. Finally, although we adjusted for the duration of hospital participation in the GWTG–Resuscitation registry, we cannot distinguish whether our findings are a consequence of motivated hospitals participating in a quality-improvement registry or part of a nationwide trend arising from other factors (such as changes in clinical practice and equipment and early recognition of illness acuity).

We found that survival after cardiac arrest improved regardless of whether or not the initial cardiac-arrest rhythm was treatable by defibrillation. In patients with ventricular fibrillation or pulseless ventricular tachycardia, improvement in survival over time was not accompanied by shorter defibrillation times. These observations suggest that factors other than rapid defibrillation may have accounted for the improvement in survival. These factors may include earlier recognition of cardiac arrest (i.e., shorter response times), quality of acute resuscitation (e.g., greater availability of trained personnel and provision of high-quality chest compressions with fewer interruptions), and postresuscitation care (e.g., therapeutic hypothermia and early cardiac catheterization). In fact, many of these processes have been emphasized in the American Heart Association Guidelines for CPR during the past decade.[25,26] Future studies are needed to better understand which specific factors are responsible for improvements in survival after cardiac arrest so that survival gains can be consolidated and expanded to all hospitals.

Several issues also merit further discussion. First, the increase in survival may simply reflect a decrease in baseline risk over time. However, we found little evidence that this was occurring. Although patients in our study were younger by approximately 1.5 years at the end of the decade than those at the beginning, with less heart disease and less baseline neurologic disability, they also had higher rates of septicemia, mechanical ventilation, and use of vasopressor medications before the arrest. Moreover, our results were consistent even after adjustment for temporal changes in patient characteristics over time, including age. Second, increasing use of advanced directives and DNR orders could have introduced selection bias in the patients who undergo resuscitation for a cardiac arrest over time. Yet again, our observed temporal increase in the proportion of patients on mechanical ventilation and vasopressor medications before cardiac arrest makes this less likely. Moreover, one study has shown that the proportion of in-hospital deaths that are preceded by CPR has actually increased over time.[10] Finally, our findings are unlikely to be due to enrollment of better-performing hospitals over time,

Table 2. Trends in Survival and Neurologic Outcomes.*

Outcome	Risk-Adjusted Rates†										Adjusted Rate Ratio per Year (95% CI)‡	P Value for Trend‡
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009		
	percent											
Survival to discharge	13.7	17.1	18.2	17.8	18.9	20.0	20.5	21.2	23.3	22.3	1.04 (1.03–1.06)	<0.001
Acute resuscitation survival§	42.7	45.1	45.4	46.0	47.0	48.6	49.7	52.5	55.2	54.1	1.03 (1.02–1.04)	<0.001
Postresuscitation survival¶	32.0	38.3	40.0	39.0	40.8	42.1	42.4	41.5	43.6	42.9	1.02 (1.01–1.03)	0.001
Neurologic outcome in survivors												
Clinically significant disability‖	32.9	35.7	31.9	34.3	34.0	33.1	33.0	32.7	31.8	28.1	0.98 (0.97–1.00)	0.02
Severe disability**	10.1	10.5	9.8	10.5	11.5	11.5	9.7	12.2	11.7	10.7	1.01 (0.98–1.04)	0.37

* CI denotes confidence interval.
† Risk-adjusted rates of survival to discharge, acute resuscitation survival, postresuscitation survival, and neurologic disability for each calendar year are reported for the overall cohort. Rates were adjusted for temporal changes in patient and hospital characteristics (see Table S4 in the Supplementary Appendix for all model covariates). Risk-adjusted rates for each calendar year were obtained by multiplying the observed rate for the reference year (2000) by the corresponding rate ratios for 2001 through 2009 from a model evaluating calendar year as a categorical variable
‡ Adjusted risk ratios and P values for trend were determined with a model evaluating calendar year as a continuous variable.
§ Acute resuscitation survival was determined by the number of patients with return of spontaneous circulation for at least 20 minutes divided by the number of patients with a cardiac arrest.
¶ Postresuscitation survival was determined by the number of patients surviving to hospital discharge divided by the number surviving the acute resuscitation.
‖ Clinically significant disability was defined as a CPC score of more than 1 in patients surviving to hospital discharge.
** Severe disability was defined as a CPC score of more than 2 in patients surviving to hospital discharge.

because we found similar results when we restricted our analyses to hospitals that participated in the GWTG–Resuscitation registry for 8 years or longer.

Our findings should be interpreted in light of the following potential limitations. First, although data in the GWTG–Resuscitation registry allowed us to adjust for a number of key variables, the possibility of residual confounding still remains. Second, we did not have detailed information on specific resuscitation-process variables (e.g., quality of chest compressions), treatments (e.g., use of hypothermia or cardiac catheterization), and quality-improvement initiatives at hospitals (e.g., use of routine mock cardiac arrests) to better understand the reasons for improved survival. These are often difficult to document accurately, and further studies are required to examine the role of these factors in explaining the temporal increase in survival. Third, data on CPC scores at discharge were missing for 14% of survivors. Therefore, our findings on the secondary outcome of neurologic disability should be interpreted with caution. Finally, although we found that improved survival trends were independent of the duration of hospital participation in the GWTG–Resuscitation registry, our study cohort was probably composed of hospitals motivated for quality improvement; therefore, our findings may not be generalizable to all hospitals in the United States.

In conclusion, we found that survival after in-hospital cardiac arrest has improved significantly during the past decade at hospitals participating in a large, national quality-improvement registry. This improvement was accompanied by a parallel decrease in rates of neurologic disability over time.

Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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