

ORIGINAL ARTICLE

Long-Term Outcomes of Out-of-Hospital Cardiac Arrest after Successful Early Defibrillation

T. Jared Bunch, M.D., Roger D. White, M.D., Bernard J. Gersh, M.B., Ch.B., Ryan A. Meverden, B.S., David O. Hodge, M.S., Karla V. Ballman, Ph.D., Stephen C. Hammill, M.D., Win-Kuang Shen, M.D., and Douglas L. Packer, M.D.

ABSTRACT

BACKGROUND

From the Departments of Internal Medicine (T.J.B., R.D.W., B.J.G., S.C.H., W.-K.S., D.L.P.) and Anesthesiology (R.D.W.); the Division of Cardiovascular Diseases, Department of Internal Medicine (R.D.W., B.J.G., S.C.H., W.-K.S., D.L.P.); and the Division of Biostatistics, Department of Health Sciences Research (R.A.M., D.O.H., K.V.B.) — all at the Mayo Clinic, Rochester, Minn. Address reprint requests to Dr. White at the Department of Anesthesiology and Division of Cardiovascular Diseases, Department of Internal Medicine, Mayo Clinic, Mayo Foundation, 200 First St. SW, Rochester, MN 55905, or at white.roger@mayo.edu.

Mortality after out-of-hospital cardiac arrest from ventricular fibrillation is high. Programs focusing on early defibrillation have improved the rate of survival to hospital discharge. We conducted a population-based analysis of the long-term outcome and quality of life of survivors.

METHODS

All patients who had an out-of-hospital cardiac arrest between November 1990 and January 2001 who received early defibrillation for ventricular fibrillation in Olmsted County, Minnesota, were included. The survival rate was compared with that of an age-, sex-, and disease-matched (2:1) control population of residents who had not had an out-of-hospital cardiac arrest and with that of age- and sex-matched controls from the general U.S. population. The quality of life was assessed with use of the Medical Outcomes Study 36-item Short-Form General Health Survey (SF-36) and compared with U.S. population norms.

RESULTS

Of 200 patients who presented with an out-of-hospital cardiac arrest with ventricular fibrillation, 145 (72 percent) survived to hospital admission (7 died in the emergency department) and 79 (40 percent) were neurologically intact (good overall capability or moderate overall disability) at discharge. The mean (\pm SD) length of follow-up was 4.8 ± 3.0 years. Nineteen patients died after discharge from the hospital. The expected five-year survival rate (79 percent) was identical to that among age-, sex-, and disease-matched controls ($P=0.68$) but lower than that among the age- and sex-matched U.S. population (86 percent, $P=0.02$). Fifty patients completed SF-36 surveys at the end of follow-up, and the majority had a nearly normal quality of life, with the exception of reduced vitality.

CONCLUSIONS

Long-term survival among patients who have undergone rapid defibrillation after out-of-hospital cardiac arrest is similar to that among age-, sex-, and disease-matched patients who did not have out-of-hospital cardiac arrest. The quality of life among the majority of survivors is similar to that of the general population.

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SURVIVAL AFTER OUT-OF-HOSPITAL CARDIAC arrest depends on a sequence of events termed "the chain of survival,"¹⁻³ which involves rapid access to emergency medical care, cardiopulmonary resuscitation (CPR), defibrillation, and advanced care.³ Several studies have shown that rapid defibrillation after an out-of-hospital cardiac arrest with ventricular fibrillation is the single most important determinant of outcome.⁴⁻¹⁰

In most places, survival rates range from 3 to 10 percent because the chain of survival is not promptly implemented, although with the increasing availability of early defibrillation the rates are improving.⁴⁻¹³ The principle of early defibrillation, strongly endorsed by the 1992 National Conference on Cardiopulmonary Resuscitation and Emergency Care,¹⁴ supports the use of this intervention by emergency personnel who are first at the scene. In the city of Rochester in Olmsted County, Minnesota, early defibrillation by police was implemented in late 1990. The rate of survival to hospital discharge with the use of this defibrillation program is 40 percent.^{6,7}

There is a paucity of data addressing long-term survival and the quality of life of survivors of out-of-hospital cardiac arrest. In Rochester and Olmsted County, survivors of ventricular fibrillation receive subsequent treatment and follow-up at one institution, a factor that facilitates long-term follow-up of this closed population. We conducted this study to determine the effect of rapid defibrillation and aggressive inpatient care on long-term survival and the quality of life.

METHODS

The study was approved by the institutional review board of the Mayo Clinic. All patients who had an out-of-hospital cardiac arrest with ventricular fibrillation between November 1990 and December 2000 and who received defibrillation from emergency personnel (police, firefighters, and paramedics) in Rochester, Minnesota, and surrounding communities in Olmsted County (populations, 85,806 and 124,277, respectively, in January 2000) were included. Data regarding the cardiac arrest and subsequent outcomes were collected in a prospective manner. We have previously reported on early survival after defibrillation among a subgroup of this cohort.⁴⁻⁷

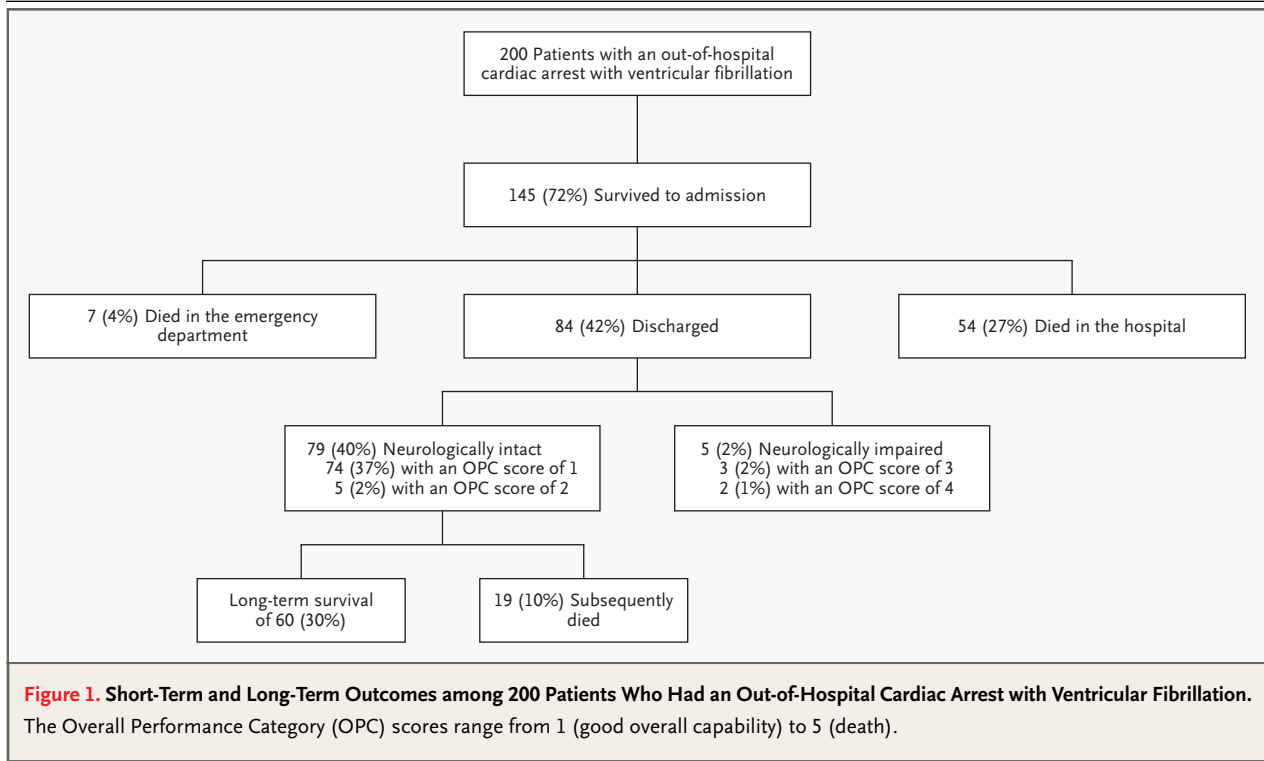
Trained personnel, primarily police officers and, in some cases, firefighters, provided defibrillation using automated external defibrillators. Paramedics provided advanced life support. In this emergency

medical system, telephone calls to 911 are received at a public-safety communications center, which then dispatches police and firefighters. The interval from the 911 call to the administration of the first shock was determined by synchronizing the defibrillator time obtained from the automated external defibrillator itself with the dispatch time recorded at the communications center.⁴⁻⁷

Emergency personnel confirmed that a patient was pulseless and then attached an automated external defibrillator; at that time CPR, if ongoing, was discontinued so as not to interfere with the device. Return of spontaneous circulation was considered to have occurred if the initial shocks restored circulation and subsequently maintained it. No epinephrine or other vasoactive drug was needed in this group of patients. Patients who required advanced life support in the absence of the return of spontaneous circulation received epinephrine, along with other drug therapy if needed, and underwent endotracheal intubation.

All patients were transported to a single hospital. The underlying cause of the cardiac arrest was established and categorized as myocardial infarction or acute coronary syndrome on the basis of electrocardiographic evidence of ST-segment elevation or angiographic evidence of acute occlusion, ischemic coronary heart disease without obvious acute coronary syndrome or myocardial infarction as previously defined, nonischemic heart disease, or some other cardiac cause with no obvious organic heart disease. The outcome in the hospital was determined. Survival was defined by an overall performance category score^{15,16} of 1 (good overall capability) or 2 (moderate overall disability — patient is conscious and performs independent activities of daily life but has moderate cerebral or noncerebral organ-system dysfunction) at hospital discharge. Patients who died in the hospital (score of 5) or who had a score of 3 (severe overall disability — patient is dependent on others for daily support and has severe cerebral or noncerebral organ-system dysfunction) or 4 (coma) at the time of discharge were considered nonsurvivors.

We ascertained the patients' vital status by reviewing the Mayo Clinic patient-data registry or by telephoning the patients' families. We assessed the long-term quality of life in a subgroup of patients from September 1, 2001, through November 30, 2001, using the Medical Outcomes Study 36-item Short-Form General Health Survey (SF-36), which assesses eight aspects of health status: general and



mental health, physical and social functioning, physical and emotional role, pain, and vitality.^{17,18} Scores on each scale can range from 0 (worst) to 100 (best).

We estimated survival rates using the Kaplan–Meier product-limit method. We determined expected survival by calculating survival rates during the decade from 1990 to 2000 in two control populations: an age- and sex-matched U.S. population and an age-, sex-, and disease-matched population of persons from Olmsted County who had not had an out-of-hospital cardiac arrest. Thus, we could compare survival rates between our group of survivors of out-of-hospital cardiac arrest and the general population irrespective of the presence or absence of cardiac disease. The Olmsted County control population consisted of patients (two for each study patient) randomly identified at the time of the study patient’s cardiac arrest and matched for the type of underlying cardiac disease (myocardial infarction or acute coronary syndrome, ischemic coronary heart disease without acute coronary syndrome, or non-ischemic dilated cardiomyopathy). We compared the rate of death from all causes in the cohort with that in the disease-matched control population using a two-sample log-rank test and with that in the

U.S. control population using a one-sample log-rank test.

We compared base-line characteristics of survivors and nonsurvivors using Fisher’s tests (for binary variables) or two-sample t-tests (for continuous variables). All tests were two-sided, and a P value of less than 0.05 was considered to indicate statistical significance. The raw scores for each of the eight SF-36 scales and overall physical and mental component scores were adjusted with the use of age- and sex-matched norms from a sample of the general U.S. population; a normalized mean (\pm SD) adjusted score of 50 ± 10 was considered normal, thus allowing easier norm-based interpretation. A one-sample t-test was used to determine whether the mean scores for each of the eight SF-36 scales differed from the population norm of 50.

RESULTS

During the study period, 330 patients had an out-of-hospital cardiac arrest of presumed or documented cardiac origin. Two hundred patients (61 percent) presented in ventricular fibrillation, 58 (18 percent) in pulseless electrical activity, and the remaining 72 (22 percent) in asystole. Only four patients (1 per-

cent) who had cardiac rhythms that were known not to respond to defibrillation survived to hospital discharge; all four had pulseless electrical activity at presentation. Details of the initial resuscitation before hospitalization have been reported previously for the entire population.⁴⁻⁷

Of the 200 patients with ventricular fibrillation, 145 (72 percent) maintained spontaneous circulation after defibrillation and were admitted to the emergency department. Figure 1 shows the outcome after admission to the hospital. Because 3 patients who were admitted to the hospital (2 of whom survived to discharge) declined to have their data released for research purposes, demographic results are subsequently reported for 142 patients (Table 1). The mean time from the 911 call to the administration of the first shock was 5.7±1.6 minutes (range, 2.0 to 9.6) among survivors and 6.6±1.5 minutes (range, 2.8 to 9.9) among nonsurvivors (P=0.002). Bystanders performed CPR on 68 patients (48 percent). The performance of CPR was not assessed in terms of its apparent effectiveness.

Table 2 lists the structural heart disease documented during the index hospitalization of the 79 survivors, as well as the revascularization treatment administered. All these patients underwent echocardiography less than 24 hours after the out-of-hospital cardiac arrest. The average ejection fraction in this group was 0.42±0.18 at base line; 30 patients (38 percent) had an ejection fraction of less than 0.40.

Among the survivors, 37 (47 percent) had a reversible cause of the out-of-hospital cardiac arrest — acute myocardial ischemia — and the primary process was treated. Although the ventricular-fibrillation arrest was considered part of the event in these 36 patients, 14 were candidates for further electrophysiological studies on the basis of the presence of persistent ischemic coronary disease, left ventricular dysfunction, and nonsustained ventricular tachycardia. The other 42 had ischemic, nonischemic, or idiopathic heart disease and were candidates for antiarrhythmic therapy. Four patients with ischemic coronary heart disease without left ventricular dysfunction underwent cardiac bypass surgery alone. Among patients who were considered candidates for antiarrhythmic therapy, 10 patients received amiodarone alone, and 35 an implantable cardioverter-defibrillator (3 also received amiodarone). The patients who did not receive antiarrhythmic therapy or an implantable cardioverter-defibrillator typically presented with a myocardial infarction with

Table 1. Base-Line Demographic Characteristics of the 142 Patients with an Out-of-Hospital Cardiac Arrest with Ventricular Fibrillation Who Were Admitted to the Hospital.*

Characteristic	Survivors (N=79)	Nonsurvivors (N=63)	P Value
Male sex (%)	84	73	0.15
Age (yr)†	61.9±15.9	68.1±14.3	0.02
Hypertension (%)	14	36	0.005
Diabetes (%)	18	21	0.67
Ejection fraction	0.42±0.18	0.32±0.15	0.01
Cardiac medication (%)			
Beta-blocker	10	12	1.0
ACE inhibitor	19	33	0.08
Calcium-channel blocker	10	18	0.22
Digoxin	14	35	0.005
Statin	19	16	0.66
Time from 911 call to administration of 1st shock (min)			0.002
Mean	5.7±1.6	6.6±1.5	
Range	2.0–9.6	2.8–9.9	
Witnessed arrest (%)	92	75	0.008
Bystander CPR (%)	52	43	0.31
Epinephrine required (%)	28	93	<0.001

* Plus-minus values are means ±SD. Three of the 145 patients declined to have their data measured for research purposes; therefore, data are reported on 142 patients. Patients who had an overall performance category (OPC) score^{15,16} of 1 (good overall capability) or 2 (moderate overall disability — patient is conscious and performs independent activities of daily living but has moderate cerebral or noncerebral organ-system dysfunction) at hospital discharge were considered survivors. Those who died in the hospital (OPC score of 5) or who had a score of 3 (severe overall disability — patient is dependent on others for daily support, with severe cerebral or noncerebral organ-system dysfunction) or 4 (coma) at discharge were considered nonsurvivors. ACE denotes angiotensin-converting enzyme, and CPR cardiopulmonary resuscitation. † One patient was less than 18 years old.

preserved cardiac function and underwent revascularization alone, declined further therapy, or had other severe noncardiac conditions that limited treatment.

Of the 35 patients who received an implantable cardioverter-defibrillator, 14 (40 percent) had subsequent shocks during follow-up; 6 received multiple shocks (range, 2 to 15). In 13 patients, the shock was triggered by ventricular fibrillation or ventricular tachycardia (1 patient had a lead fracture that induced an inappropriate shock).

The average interval from discharge to the last contact with the patient or death was 4.8±3.0 years. Nineteen patients died during follow-up; thus, the expected five-year survival rate was 79 percent.

Table 2. Structural Heart Disease Identified and Revascularization Treatments Undertaken in 79 Patients Who Survived and Were Neurologically Intact at Hospital Discharge.

Structural Heart Disease	No. (%) of Patients
Myocardial infarction or acute coronary syndrome	37 (47)
Percutaneous catheter-based intervention	15 (19)
Coronary-artery bypass grafting	4 (5)
Ischemic coronary heart disease without obvious acute coronary syndrome	25 (32)
Percutaneous catheter-based intervention	5 (6)
Coronary-artery bypass grafting	10 (13)
Nonischemic heart disease	10 (13)
Dilated cardiomyopathy	5 (6)
Alcohol-induced cardiomyopathy	2 (3)
Long-QT syndrome	2 (3)
Infiltrative cardiomyopathy (hemochromatosis)	1 (1)
No obvious organic heart disease	7 (9)

Three patients had a second ventricular-fibrillation-induced arrest during follow-up, one of whom survived. Overall, only 5 of 79 patients (6 percent) died of cardiac disease (2 from recurrent cardiac arrest). Deaths from noncardiac causes included five from cancer, three from complications of a cardiovascular accident, two from chronic obstructive pulmonary disease, one from a hip fracture, one from liver failure, one from advanced dementia, and one from an unknown cause in the setting of severe alcohol abuse.

Figure 2 compares the overall expected survival rate among the 79 survivors with the rate in the control groups; the survival rate at five years was lower than that among the age- and sex-matched U.S. population ($P=0.02$), but similar to that among the age-, sex-, and disease-matched population ($P=0.68$).

Of the five patients who were considered non-survivors because they had severe neurologic impairment at hospital discharge (as defined by an overall performance category score of 3 or 4), two have died. The three patients with an overall performance category score of 3 were discharged to institutional care, each requiring medications for behavioral control: two were alive at the time of the last follow-up visit (36 and 24 months after cardiac arrest), and one died after 7 months. One of the two patients with an overall performance category score of 4 was discharged to receive ongoing care in his home country after two months with no improvement in his condition (and was subsequently lost to

follow-up); the other was discharged to a nursing care center and died three months later.

Of 60 patients who were alive at the time of the last follow-up visit, 50 completed the SF-36; 5 declined, 1 was excluded as a minor, 2 were physically or mentally unable to participate (1 had severe psychiatric disease before the out-of-hospital cardiac arrest and 1 had advanced dementia), 1 was engaged in military service and could not be contacted, and 1 had incomplete contact information. A review of the medical charts of the minor and three of the five patients who declined to fill out the SF-36 suggested that all had returned to normal activities with no limitations. Of the other two, one had progressive heart failure approximately eight years after the out-of-hospital cardiac arrest and the other was limited by advanced noncardiac disease. The three surviving patients who had overall performance category scores of 3 or 4 at hospital discharge were not assessed.

The normalized SF-36 scores for the 50 long-term survivors are compared with those of the U.S. general population in Figure 3. There was no significant difference between the groups except in the vitality score — a measurement of the extent one feels tired or worn out ($P=0.01$). Twenty-six of the 45 patients who responded to the vitality question (58 percent) were able to return to work; 65 percent of the patients who were younger than 65 years of age returned to work.

DISCUSSION

In this population-based study of the outcomes of a program of rapid defibrillation, patients who survived to hospital discharge had a long-term survival rate equivalent to that of age-, sex-, and disease-matched patients who did not have an out-of-hospital cardiac arrest. A nearly normal quality of life and return to work were reported by the majority of survivors who completed the quality-of-life assessment. These data serve as a benchmark and illustrate what can be achieved in a community setting with an aggressively implemented program of early defibrillation.

As we have reported previously,⁴⁻⁷ survival after ventricular fibrillation in this cohort was relatively high. Previous studies of patients with an out-of-hospital cardiac arrest with ventricular fibrillation have reported survival rates after hospital discharge ranging from 3 to 33 percent in a variety of settings.⁸⁻¹³ In communities without access to early

defibrillation, mortality rates exceed 90 to 95 percent.^{12,13} In contrast, in communities that have programs of early defibrillation, survival rates of 15 to 40 percent have been reported.^{4-7,10,11,19,20} In Rochester, Minnesota, during a four-year historical-control period before the implementation of the early-defibrillation program in 1990, the rate of survival to discharge was 28 percent. In the current study, the rate was 40 percent after the program was implemented. This value represents a 200 to 300 percent increase in survival as compared with reported outcomes in other locations^{8-13,19,20} and is most likely due, at least in part, to the relatively short interval between the 911 call and the administration of the first shock and to aggressive early management in the hospital.

The expected long-term survival rate among this population of patients who had an out-of-hospital cardiac arrest with ventricular fibrillation was 79 percent five years after discharge. The expected five-year rate of freedom from death from a cardiac cause was 92 percent, and the rate of overall survival was slightly lower than rates in the general U.S. population but identical to that in age-, sex-, and disease-matched controls. It is likely that the use of revascularization of culprit lesions and antiarrhythmic therapy in the hospital, coupled with the higher survival rate associated with early defibrillation, increased the long-term survival rate.

Many factors may have predisposed the survivors to an increased risk of subsequent death. First, this population had already had a ventricular-fibrillation-induced cardiac arrest. The survival rate in our population was higher than projected or actual mortality rates at three to five years in other populations with ventricular arrhythmias.^{21,22} For example, the five-year mortality rate among patients with a history of cardiac arrest in the Cardiac Arrest Study Hamburg was 36 percent in the group that received an implantable cardioverter-defibrillator and 44 percent in the group that received antiarrhythmic therapy.²² In a subgroup analysis of 98 patients in the Canadian Implantable Defibrillator Study who presented with out-of-hospital cardiac arrest, the total mortality rate was 18.4 percent at two years and 33.4 percent at five years. Second, although the rate of death from cardiac causes was low, recognized predictors of adverse outcomes (multivessel coronary heart disease, diabetes, left ventricular dysfunction, and congestive heart failure)²³ were prevalent among our cohort. Furthermore, the high prevalence of death from noncardiac causes in this

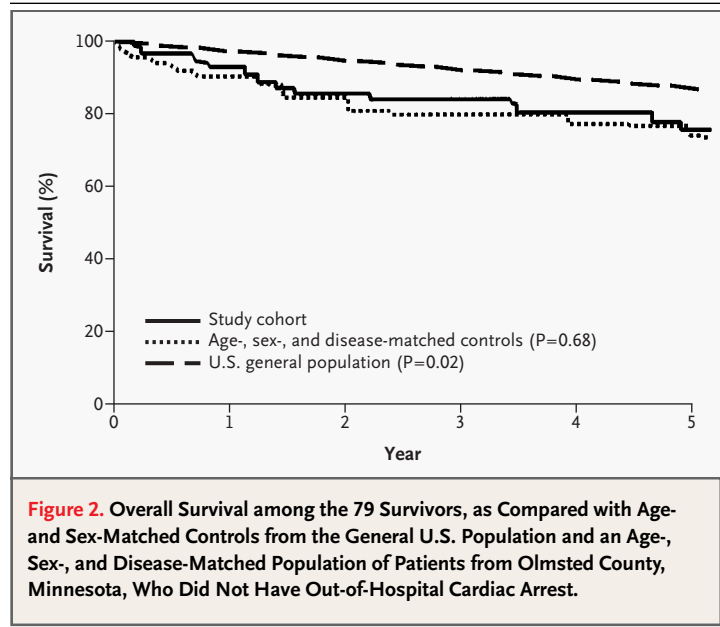


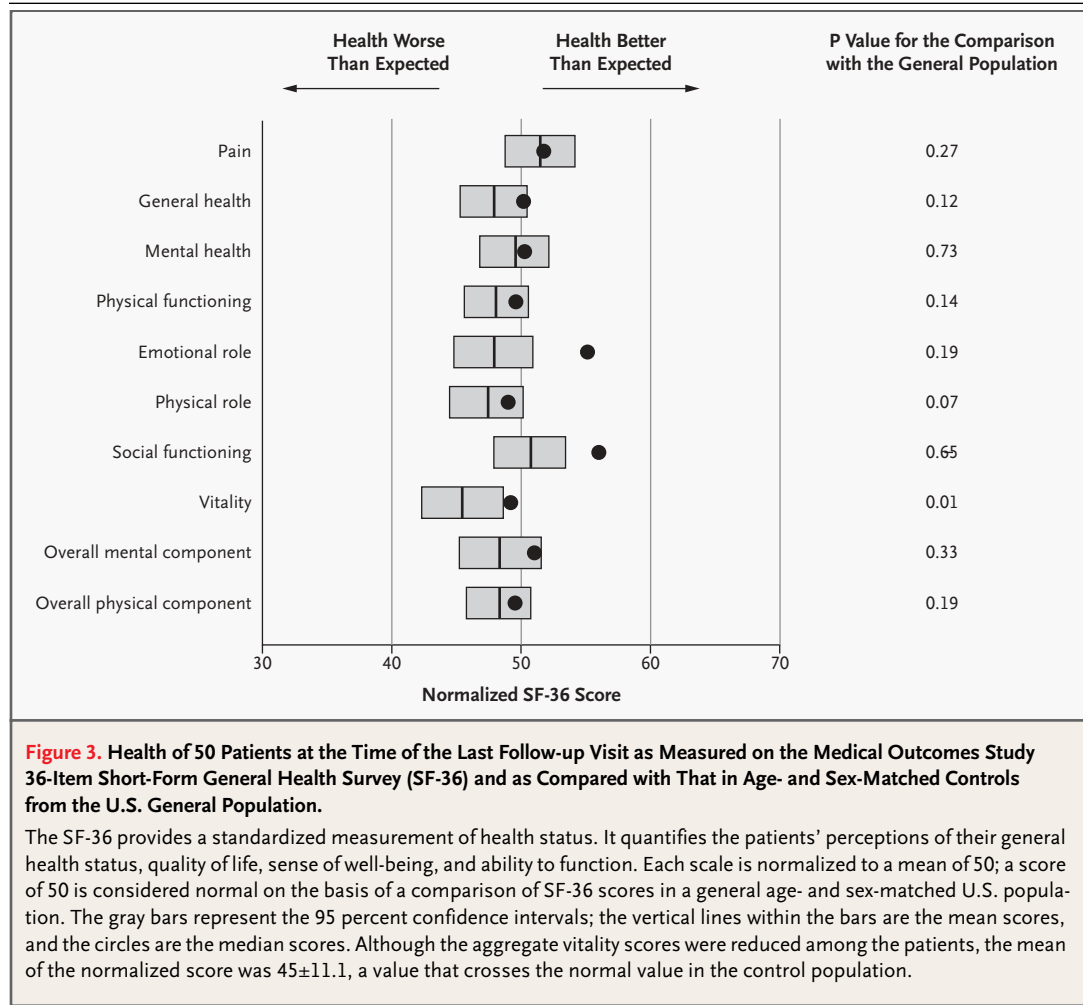
Figure 2. Overall Survival among the 79 Survivors, as Compared with Age- and Sex-Matched Controls from the General U.S. Population and an Age-, Sex-, and Disease-Matched Population of Patients from Olmsted County, Minnesota, Who Did Not Have Out-of-Hospital Cardiac Arrest.

study reflects a population at high risk for death as a result of other coexisting diseases.

Previous studies assessing the quality of life were small, focused on short-term recovery rates (at 3 to 12 months), or used only a subjective assessment tool with broad categories, such as the cerebral performance scale.²⁴⁻³¹ We used the standardized SF-36, and the results indicated that the majority subsequently had a nearly normal quality of life similar to that of the general population, with the exception of the degree of vitality. The difference between groups was moderate; vitality scores in the cohort were within 1 SD of U.S. norms. Also, vitality, as measured by the SF-36, may improve with rehabilitation among patients with cardiac disease.³²

These findings in a closed population differ from those of previous studies, which reported a decreased quality of life among survivors of out-of-hospital cardiac arrest, with a small percentage returning to work.²⁴⁻²⁸ They validate the results of previous open studies, which reported an acceptable quality of life approximately six months,²⁹⁻³¹ one year,³³ and seven years³⁴ after cardiac arrest. In addition, the majority of our patients with long-term follow-up returned to work (65 percent of those who were less than 65 years of age), thus confirming and expanding previous reports that many survivors of out-of-hospital cardiac arrest return to their previous occupation within six months.²⁹⁻³¹

Our study has several limitations. First, the re-



sults were derived from a population base of approximately 100,000 people. The Rochester, Minnesota, rapid-response program could be difficult to replicate in large cities with skyscrapers. Nevertheless, in such settings, these outcomes might be achieved through the placement of automated external defibrillators on several floors of high-rise structures and the training of security officers in their use.

Second, only patients who presented with ventricular fibrillation were included. This was by design, since we chose to assess the effect of rapid defibrillation on survival and subsequent quality of life. During the study period, 130 of those who had an out-of-hospital cardiac arrest (39 percent)⁴⁻⁷ presented in rhythms that were not treatable with defibrillation.

Third, the five-year survival rate was 79 percent in this population. With respect to the quality of life, the results could reflect a subgroup of healthier pa-

tients who were alive at follow-up and were able to respond to the survey. However, since the overall rate of death from cardiac causes after discharge was low, these data overall still provide substantial insight into the long-term quality of life of patients with underlying cardiac disease.

Fourth, the results with respect to the quality of life are collective and may not be applicable to individual patients. Furthermore, 10 of 60 patients did not complete the survey. Although the inclusion of these patients did not alter the survival analysis, it might have changed the results of the quality-of-life analysis. In addition, five patients sustained permanent neurologic injury (as defined by an overall performance category score of 3 or 4) and were not surveyed.

Finally, the use of CPR by bystanders in the system we studied has not affected the rate of survival after out-of-hospital cardiac arrest with ventricular

fibrillation.⁴⁻⁶ Previously, we reported that there was no significant difference in the rates of bystander-administered CPR between patients who survived out-of-hospital ventricular fibrillation and those who did not survive (42 percent vs. 58 percent, $P=0.74$).⁶ This finding was replicated in the current study, which included three additional years of follow-up. This finding may reflect the relatively short interval between the 911 call and the administration of the first shock and should therefore not be misinterpreted to apply to other settings involv-

ing longer intervals before defibrillation can be attempted.

In summary, the rate of survival to hospital discharge was relatively high in a city that had a program of rapid defibrillation. The majority of survivors returned to work, and their quality of life was in most respects indistinguishable from that of the general population. The long-term survival rate was similar to that of age-, sex-, and disease-matched controls who did not have an out-of-hospital cardiac arrest.

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