Tripling Survival From Sudden Cardiac Arrest Via Early Defibrillation Without Traditional Education in Cardiopulmonary Resuscitation

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***Background*—**Early defibrillation is the most important intervention affecting survival from sudden cardiac arrest (SCA). To improve public access to early defibrillation, we established Piacenza Progetto Vita (PPV), the first system of out-of-hospital early defibrillation by first-responder volunteers.

***Methods and Results*—**The system serves a population of 173 114 residents in the Piacenza region of Italy. Equipment for the system comprises 39 semiautomatic external biphasic defibrillators (AEDs): 12 placed in high-risk locations, 12 in lay-staffed ambulances, and 15 in police cars; 1285 lay volunteers trained in use of the AED, without traditional education in cardiac pulmonary resuscitation, responded to all cases of suspected SCA, in coordination with the Emergency Medical System (EMS). During the first 22 months, 354 SCA occurred (72±12 years, 73% witnessed). The PPV volunteers treated 143 SCA cases (40.4%), with an EMS call-to-arrival time of 4.8±1.2 minutes (versus 6.2±2.3 minutes for EMS, $P=0.05$). Overall survival rate to hospital discharge was tripled from 3.3% (7 of 211) for EMS intervention to 10.5% (15 of 143) for PPV intervention ($P=0.006$). The survival rate for witnessed SCA was tripled by PPV: 15.5% versus 4.3% in the EMS-treated group ($P=0.002$). A "shockable" rhythm was present in 23.8% (34 of 143) of the PPV patients versus 15.6% (33 of 211) of the EMS patients ($P=0.055$). The survival rate from shockable dysrhythmias was higher for PPV versus EMS: 44.1% (15 of 34) versus 21.2% (7 of 33), $P=0.046$. The neurologically intact survival rate was higher in PPV-treated versus EMS-treated patients: 8.4% (12 of 143) versus 2.4% (5 of 211), $P=0.009$.

***Conclusions*—**Broad dissemination of AEDs for use by nonmedical volunteers enabled early defibrillation and tripled the survival rate for out-of-hospital SCA. **(*Circulation*. 2002;106:1065-1070.)**

Key Words: resuscitation ■ defibrillation ■ heart arrest

Sudden cardiac arrest (SCA) claims an estimated 350 000 lives per year in the United States, representing a major public health problem.[1] The vast majority of SCA is caused by ventricular fibrillation (VF) (85%),[2] in which early defibrillation is the most important intervention affecting survival.[3–6] After 10 minutes, very few resuscitation attempts are successful (0% to 2%).[7] The major determinants of survival after witnessed out-of-hospital SCA include bystander initiation of cardiopulmonary resuscitation (CPR) and the rapidity with which defibrillation is accomplished.[8] Unfortunately, most victims do not have immediate access to prompt, effective treatment, and too much time elapses before the defibrillator arrives, if it arrives at all. Although bystander CPR (consisting of precordial compression and ventilations) has often been associated with improved survival from SCA, it cannot substitute for the definitive treatment of defibrillation.[4–6] It is worth considering, in fact, that CPR may primarily serve as a correlate of a prompt call for help and early defibrillation rather than offering any direct benefit on survival. Historically, only 2% to 5% of victims of SCA have been resuscitated with the commonly used Emergency Medical System (EMS) approach.[9]

On the other hand, 2-tier response systems in which the EMS oversees the activities of lay volunteers equipped with automatic external defibrillators (AEDs) has considerable promise. In Rochester, Minnesota, for example, use of police equipped with AEDs has resulted in an average response time of 6 minutes, with a 45% survival rate for witnessed VF.[10] Similarly positive experiences have been reported in select locations such as aircraft and casinos.[5,6]

We have taken this approach one step further by focusing almost exclusively on improving defibrillation response times with the use of lay volunteers. The role of traditional CPR in SCA survival has been recently disputed, given both the poor

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CPR skill performance and retention by people not currently involved in cardiac resuscitation[11,12]; thus we focused our effort on training the lay volunteers to perform only early defibrillation by using an AED.

Our approach, called Piacenza Progetto Vita (PPV), was initiated June 6, 1999. It is the purpose of this report to examine our results for the first 22 months of this endeavor.

Methods

Response System

Piacenza is a mid-sized town (99,878 inhabitants in the city and 163,353 additional inhabitants in the surrounding region). In 1990, an EMS, located in the city center, was organized to coordinate the response to health emergencies. Within this system, the EMS is alerted to a possible SCA by a "118" telephone call, at which time an ambulance with physician assistance and a defibrillator are immediately dispatched.

To supplement this capability, the PPV was established to enable rapid defibrillation by lay responders (nonmedical personnel) equipped with AEDs. Twelve fixed-location AEDs were placed in the main public squares, the university, the stadium, athletic centers, the post office, and the railway station. Mobile AEDs were placed in selected vehicles: 15 in police and fire vehicles and 12 more in the vehicles of the Public Assistance, a nonprofit organization of volunteers participating in the assistance and transportation of the ill. Thus, 39 AEDs were deployed to cover a population of 173,114 inhabitants (66% of the regional population), or 1 AED per 4438 inhabitants. During the study period, 1285 lay volunteers were trained for participation in the PPV response program.

The PPV system is organized to work in full collaboration with the local EMS. All suspected SCA emergencies initiate a coordinated response. The "118" telephone dispatcher asks the caller one specific question "Is the patient conscious or awake?" If answered in the negative, the dispatcher activates a "code blue" resulting in (1) dispatch of a medical ambulance by the EMS, (2) a telephone call to the PPV volunteer with the nearest mobile AED, and (3) a telephone call to the PPV volunteers at the nearest fixed AED location.

Training

All lay volunteers operate under the medical responsibility of the chief of the EMS department, who authorizes the training courses and the qualifying examination required by the first responders, with the use of international guidelines.[17,18] Training courses for the lay volunteers include 4 hours of theoretical and practical lessons. Four instructors train 12 volunteers during each session. In particular, participants are instructed to recognize the absence of consciousness, the absence of breathing, and to check for signs of circulation. If none are present, they are instructed to turn on the AED and to follow the voice instructions of the AED. The time from activation of the device to initial AED analysis is calculated during training and during actual use, as a measure of the level of skill. No specific instruction for CPR (precordial compression and ventilation) is provided. A final examination is also performed.[13] At 6-month intervals, all certified lay volunteers are given a 1-hour review test with a practical examination.

The 1285 volunteers trained during the study period include policemen, financial guards, town guards, fireman, railway station personnel, ambulance personnel, post office personnel, pharmacy personnel, lifeguards, and other motivated volunteers. Trained volunteers staged mock SCA scenarios at various locations to determine the reliability and efficiency of the system and the length of time required to respond with an AED to the patient's side.

Defibrillator Descriptions

The AED devices used in the PPV system are Heartstart FR semiautomatic biphasic defibrillators (Philips Medical Systems, Heartstream Operation). The EMS ambulances use biphasic Life-Pack 12 (PhysioControl) manual defibrillators or Heartstart FR semiautomatic defibrillators.[14,15]

Protocol

The PPV volunteers follow the default defibrillation protocol provided by the AED manufacturer. The AED delivers fixed energy at 150-J, 100-μF impedance-compensating biphasic shocks. Between successful defibrillations, the AED monitors the patient's ECG for refibrillation. If detected, voice guidance is provided to the volunteer, and the AED charges for another shock. If 3 successive unsuccessful shocks are delivered, the AED initiates a 1-minute pause interval. Although this pause is intended for the performance of traditional CPR, the PPV volunteers are not instructed to do so. Responsibility for the resuscitation effort is transferred to the EMS on their arrival, whereupon standard European Resuscitation Council guidelines are followed. For resuscitations in which the AED is initially applied, use of the manual defibrillator is at the discretion of the medical staff at the scene.

Objectives

The primary objective of the study was to determine resuscitation rates (admission to hospital) and survival rates (discharge from hospital). Survival rates were determined with respect to (1) the total number of cases treated (ie, overall survival rate), (2) witnessed SCA only, and (3) SCA associated with VF. Other observations included response times, the presenting cardiac rhythm, and the level of neurological recovery for survivors. Since PPV volunteers are not trained in pulse detection, return of spontaneous circulation was not evaluated.

A number of system metrics were also developed. The "code blue" dispatches were evaluated to assess the specificity of the question asked by the dispatcher during the phone interview to determine whether or not SCA was probably present. AED skill retention was evaluated by the percentage of lay volunteers who passed the 6-month follow-up examination.

Data Collection

Patient data for all out-of-hospital SCAs from June 6, 1999, to April 30, 2001, were recorded on standardized forms and compiled in the central database of the Emergency Department. Audio recordings, event information, and ECG tracings were recorded on the data card incorporated into the AED.

Assessment of neurological recovery was performed by clinical examination at hospital discharge: Patients were coded as having 4 functional levels, based on previously published criteria.[8] This classification included level 1 (full or nearly full neurological recovery), level 2 (major memory loss, naming difficulties, coordination deficit), level 3 (patient awake but with impaired neurological status), and level 4 (patient unresponsive and comatose or vegetative).

For both PPV and EMS, response times were recorded as follows: the time at which the emergency telephone call was received, the departure time of the ambulance from the hospital, and the arrival time on the scene by both PPV lay volunteers and EMS staff. The internal clocks of the AEDs were synchronized with the EMS Central Station. The central computer system computed the time intervals in minutes (seconds were not measured). The impact of the time of arrival of first responders was specifically investigated, comparing the cases that were rescued with the remaining patients who did not survive.

For the patients in shockable rhythm (VF/ventricular tachycardia [VT]), the ECG amplitude was recorded at the time of electrode pad application and immediately before shock delivery.

Statistical Analysis

Data are presented as mean$\pm$SD. For continuous variables, the *t* test (1- or 2-tailed) or the Mann-Whitney rank sum test was applied to assess differences in means between cases treated conventionally and by lay volunteers; the χ^2 test and Fisher's exact test were used to estimate the significance of differences in 2$\times$2 and other contin-

TABLE 1. Comparison of Resuscitation and Survival Rate From Sudden Cardiac Arrest in Piacenza Progetto Vita vs Emergency Medical System–Treated Patients

	Overall	PPV	EMS	P (PPV vs EMS)
SCA, n (%)	354	143 (40.4)	211 (59.6)	<0.001
Resuscitation rate	34/354 (9.6)	19/143 (13.3)	15/211 (7.1)	0.053
Survival rate	22/354 (6.2)	15/143 (10.5)	7/211 (3.3)	0.006
Neurologically intact	17/354 (4.8)	12/143 (8.4)	5/211 (2.4)	0.009
Witnessed, n (%)	261/354 (73.7)	97/143 (67.8)	164/211 (77.7)	0.038
Resuscitation rate	34/261 (13.0)	19/97 (19.6)	15/164 (9.1)	0.015
Survival rate	22/261 (8.4)	15/97 (15.4)	7/164 (4.3)	0.002
Neurologically intact	17/261 (6.5)	12/97 (12.3)	5/164 (3.0)	0.003
Shockable rhythm, n (%)	67/354 (18.9)	34/143 (23.8)	33/211 (15.6)	0.055
Resuscitation rate	34/67 (50.7)	19/34 (55.9)	15/33 (45.4)	NS
Survival rate	22/67 (32.8)	15/34 (44.1)	7/33 (21.2)	0.046
Neurologically intact	17/67 (25.3)	12/34 (35.3)	5/33 (15.1)	0.058

gency tables. Comparisons with probability values ≤0.050 were considered statistically significant and are reported as a trend of interest if ≤0.100. Comparisons with probability value >0.100 are reported as not significant.

Results

Enrollment

During the 22-month study period, a total of 354 SCA events occurred in the area covered by PPV (Table 1). The mean age of the victims was 72±12 years; 61% were male. The majority of arrests, 86.7%, occurred in the home. Arrests in public locations accounted for the remaining 13.3% as follows: 10.7% in public streets, 0.43% in an athletic center, 1.08% at work, and 1.1% in other places. The SCA was witnessed in 73.7% of the cases.

Of the 354 SCA patients, 40.4% were initially treated by the lay volunteers of the PPV versus 59.6% treated only by EMS staff (P<0.001). There was no difference in age (years: 69±12 versus 74±15) or sex (male: 57% versus 64%) between the two groups (P=NS in all comparisons).

Although the percentage of witnessed SCA was lower in the PPV group (67.8% versus 77.7%, P=0.038), a trend toward a higher percentage of "shockable" VF/VT rhythms was observed (23.8% versus 15.6%, P=0.055). Asystole was the most common presenting rhythm for both groups (Table 2).

TABLE 2. Comparison of Presenting Rhythms

	Overall	PPV	EMS
Shockable rhythms	67	34 (23.8%)	33 (15.6%)
Ventricular fibrillation	66	33	33
Ventricular tachycardia	1	1	0
Nonshockable rhythms	275	109 (76.2%)	166 (78.7%)
Asystole	247	98	149
Pulseless electrical activity	22	7	15
Atrioventricular block	6	4	2
No ECG recording	12	0	12 (5.7%)
Total	354	143	211

Efficacy, Resuscitation, and Survival

For the 354 patients with cardiac arrest who were treated during the study period, the overall resuscitation and survival rates were 9.6% and 6.2%, respectively (Table 1). Although there was no age difference between the group of survivors and nonsurvivors (64±17 versus 66±7.5 years), a significantly lower EMS call to arrival time was associated with the survivor group (4.8±1.2 versus 6.2±2.3 minutes, P<0.05). Those patients initially treated by PPV volunteers exhibited a trend toward higher resuscitation rates than those treated by EMS (13.3% versus 7.1%, P=0.052); the rate of survival to hospital discharge was tripled (10.5% versus 3.3%, P=0.006), and neurologically intact survival was more than tripled (8.4% versus 2.4%, P=0.009).

In the case of witnessed SCA, the resuscitation rate was doubled (19.6% versus 9.1%, P=0.015), the survival rate was tripled (15.4% versus 4.3%, P<0.001), and neurologically intact survival was quadrupled (12.3% versus 3.0%, P=0.003) (Table 1).

For SCA patients with "shockable" presenting rhythms, for example, VF or VT, both PPV and EMS groups had similar rates of initial resuscitation (56% versus 45%, P=NS), but survival to hospital discharge was significantly higher for the PPV group (44.1% versus 21.2%, P=0.046), and neurologically intact survival was twice as high in the PPV group, although it did not reach statistical significance (35.3% versus 15.1%, P=0.058) (Table 1).

Defibrillation was highly effective regardless of whether treatment was administered by PPV or EMS (87.5% versus 86.2% first-shock efficacy, P=NS), with none of the patients requiring more than 2 shocks to terminate the initial arrhythmia.

Ventricular fibrillation signal amplitude was not predictive of defibrillation shock success. For successful shocks, the presenting VF amplitude was 0.75±0.49 mV, compared with 0.65±0.25 mV for the ineffective shocks (P=NS). Similarly, there was no significant difference in VF amplitude immediately before shock delivery (0.52±0.38 mV versus 0.35±0.12 mV, P=NS).

TABLE 3. Time Intervals of Intervention

	PPV	EMS
Collapse to 118 phone call	NA	NA
118 Call to system activation, min	2.5±0.5*	1.0±0.5
EMS ambulance intervention		
118 Call to arrival at the scene of the event, min	4.8±1.2	6.2±2.3†
Arrival to defibrillation, s	40±13	NA

*Estimated.
†$P=0.050$.

Neurological Evaluation

Of the 22 subjects discharged alive from the hospital, 3 patients had serious neurological deficit, that is, level 3 neurological recovery: 1 from the EMS group (1 of 7) and 2 from the PPV group (2 of 15). Two patients had level 2 neurological recovery at hospital discharge (1 from each group), and the remaining 17 patients were at level 1 neurological recovery.

The neurologically intact survival rate for SCA victims initially treated by PPV was 8.4% (12 of 143) compared with 2.4% (5 of 211) for those treated by EMS ($P=0.009$). For those patients presenting with shockable rhythm, the survival rate free from neurological deficit in the PPV versus EMS groups was 35.3% (12 of 34) and 15.1% (5 of 33), respectively ($P=0.058$).

Lay Volunteer Competency

The PPV volunteers needed an average time of 40±13 seconds for application of the AED (Table 3). In 143 uses, the AED showed 100% sensitivity and 100% specificity in the recognition of shockable or nonshockable rhythms, and its interventions were all appropriate. All AED interventions were performed by mobile AEDs, whereas fixed AEDs were never used. At the retraining course, only 16 volunteers of the 1285 originally trained (1.2%) failed the review test.

Code Blue Intervention Times

A total of 366 telephone calls resulted in PPV activation. Of these, only 143 were true SCA (39.1%), whereas the remaining 223 classifications (60.1%) represented "false" SCA, for example, stroke, transient ischemic attack, seizure, or syncope, misdiagnosed by the dispatcher interview. Thus, the specificity of the dispatcher interview question, "Is the patient conscious or awake?" was poor.

The time interval from 118 call to EMS dispatch was 1.0±0.5 minutes. Since PPV volunteers are activated after EMS notification, their dispatch time is correspondingly longer, estimated at 2.5±0.5 minutes.

Despite this longer dispatch interval, PPV volunteers were more likely to be first on the scene for arrests in public places (22.4% versus 7.1%, $P<0.0001$). Additionally, the time interval from 118 call to arrival at the scene was significantly shorter for PPV volunteers (4.8±1.2 versus 6.2±2.3 minutes, $P=0.05$) (Table 3).

The average time of arrival of the first responders was significantly lower for the successfully resuscitated patients versus those who did not survive (4.5±2.1 versus 6.2±2.7 minutes, respectively, $P<0.001$). Similar shorter intervention times were observed in both PPV-treated (4.4±2.1 versus 5.7±1.7 minutes, $P<0.05$) and EMS-treated (4.5±2.6 versus 6.3±2.4 minutes, $P<0.05$) patients for the successfully treated cases compared with the nonsurvivors.

Discussion

The key factor in combating out-of-hospital SCA is early defibrillation. Over the past few decades, attempts at increasing SCA survival by EMS system improvements have proven futile. Studies in Scotland and England have demonstrated that the odds of survival to hospital discharge were not improved by either the number of trained paramedics or by the length of their experience.[16,17]

After a relatively short experience with the PPV, several important and novel findings have been observed.

First, the integration of lay volunteers trained in early defibrillation with the EMS performed better than the EMS system alone. The rate of survival to hospital discharge was significantly higher in the group of patients treated first by lay volunteers than in the patients treated first by EMS.

Second, in our project, early defibrillation took priority over all other interventions when an AED was available. A simple method of training in early defibrillation (without CPR instruction) creates a group of competent AED operators. Training of large numbers of volunteers with this type of instruction is feasible, reliable, safe, and cost-effective.

Third, lay volunteers are able to retain the skill of AED operation even 6 months subsequent to a short training course of only 4 hours.

Fourth, no negative consequences have been recorded, and although there was some preliminary fear on the part of community authorities, no adverse consequences from AED use by lay personnel have been observed.

Five, public awareness and support were crucial to the success of PPV. The development of community awareness of the project and the need for a cooperative effort to support a dedicated task force created a campaign that energized ordinary citizens and political leaders alike. Likewise, the media served as an influential ally.

As pointed out before, this project was carried out in a moderate-sized city; consequently, our results may not be applicable to other types of communities. Thus, system design and impact must be reconsidered if a similar strategy is to be applied in settings of different sizes, either larger cities or sparsely populated rural areas.

Why Public Access Defibrillation?

Lay persons are the most likely to arrive first at the scene of an arrest. There is unequivocal evidence showing the inverse relation between time to first defibrillation and survival from VF, as in the airline[5] and the casino experiences.[6,18] These reports support the idea that defibrillators should be widely available and accessible.[19,20] The evidence of improved survival with early defibrillation coupled with important AED technological advances has led to international action to increase public access to early defibrillation. This concept obtained international recognition when the American Heart Association supported reducing the time to the intervention, through public access defibrillation, as one of their major objectives.[19]

Our original idea, which has driven this endeavor, was that the first step in improving SCA survival was to train and allow more people to defibrillate while waiting for EMS arrival. The AED automatically identifies a shockable rhythm and guides the user in performing defibrillation.[21,22] Furthermore, most AEDs are now designed for use by nonmedical personnel such as police, firefighters, flight attendants, security guards, and other lay rescuers.[23]

To reduce the initial economic, legal, and practical difficulty encountered in training lay citizens in CPR, we developed the project based on the concept that CPR per se was relatively inconsequential when early defibrillation was provided. It is also important to remember that only ≈15% of lay persons instructed in CPR are unequivocally willing to perform CPR on a stranger if it requires mouth-to-mouth ventilation.[24] New international protocols have been recently approved to allow more suitable lay person CPR (ie, chest compression alone), but chest compression alone does not improve survival.[25]

PPV: Response Time Reduction and Improvement in Neurologically Intact Survival

Before the initiation of the PPV project, the ambulances of our EMS system had already been equipped with defibrillators. With response times beyond 6 minutes, this solution alone appeared to be inadequate for prompt response to SCA.

The PPV reduction of the response time by slightly more than 1 minute has allowed us to more than triple the survival rate. These findings are consistent with previous reports that each minute of delay decreases survival by 10%.[10] The favorable neurological status of patients discharged alive is also consistent with the reduction in defibrillation time.

The higher survival rate and improved neurological outcome of PPV patients is no doubt partially attributable to the 1-minute response time reduction achieved by the PPV volunteers.

The significant shorter arrival times of the first responders for the saved patients with respect to nonsaved cases further supports the impact of the intervention time on the favorable outcomes, as recommended by international guidelines,[19] which may be accomplished by a program of widespread early defibrillation, such as the PPV project.

Additional benefit may have resulted from the use of lower-energy biphasic shocks compared with EMS responders (150 J versus 200 to 360 J). Significantly reduced postresuscitation myocardial dysfunction has previously been observed in an animal model of prolonged cardiac arrest when using low- versus high-energy biphasic defibrillation.[26] The investigators of this study stated that "increasing the number of neurologically intact survivors from out-of-hospital sudden cardiac arrest may directly depend on reducing the compromise of cardiac output associated with high-energy defibrillation."

Furthermore, our results suggests that it is possible to develop and organize an effective system for early defibrillation funded primarily by community contributions and nonprofit organizations, a finding in keeping with the experience of other centers.[27] Fund-raising efforts yielded ≈$270,000 (US) to acquire 39 AEDs and train 1285 volunteers for the PPV system. This was made possible by public support generated through education efforts with the help of the local radio and news networks and the contributions of not-for-profit international foundations (see Acknowledgments).

Improvements

Although the PPV results are successful and encouraging, improvements should be considered. The high percentage of patients with asystole suggests that further reductions in response time are still necessary to obtain a larger group of patients with shockable rhythms. The absence of a single emergency telephone number in Italy makes communication between the "118" dispatcher and the police station system difficult. The consequence is an estimated delay of 1 to 2 minutes before the rescue cars can be activated (Table 3).

The majority of the SCAs occurred at home (86.7%), and none occurred in proximity to a fixed AED, which were consequently never used. Furthermore, many patients rescued by PPV volunteers were found in public places, whereas only a minority (43.5%) occurred in patients' homes. For an SCA occurring in a public place, it is likely that the time to call "118" was immediate, and the downtime was consequently reduced sufficiently to benefit the rescue of patients by the PPV. When SCA occurred at home, however, the events were often unwitnessed, and clear information from the relatives and/or neighbors may have been difficult to obtain. Instead of interpreting this finding as an argument against fixed-location AEDs, one could have the opposite concern—that there are not enough AEDs in fixed public locations and that the populace should be made more aware of their presence and how to use them.

For the future, we plan to make further investments in educating the community at large about the importance of a prompt "118" activation. This will be achieved by a public education effort within the schools and by the mass media.

The "118" dispatcher often misdiagnosed the occurrence of SCA, and in 73.4% of the cases incorrectly activated the "code blue." The occurrence of false-positive intervention was taken into account when the PPV was started, but once again, improved training of the "118" dispatcher could be considered. Nevertheless, a high false-positive rate may be necessary in order to have a high sensitivity to SCA.

Conclusions

The importance of an early defibrillation program by lay volunteers equipped with AEDs in Europe is now well documented. The program is reliable, safe, and cost-effective. The integration of early defibrillation performed by lay volunteers into the EMS system allowed us to dramatically reduce mortality rates, thereby tripling overall and neurologically intact survival rates from SCA. Early defibrillation alone, without CPR, is better than a traditional EMS system because of the reduction in time for definitive intervention. A simple 4-hour AED training program may be sufficient to reach higher survival rates.

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