Improved Outcome for Prehospital Cardiopulmonary Collapse with Resuscitation by Bystanders

DONALD P. COPLEY, M.D., JOHN A. MANTLE, M.D., WILLIAM J. ROGERS, M.D., RICHARD O. RUSSELL, JR., M.D., AND CHARLES E. RACKLEY, M.D.

SUMMARY Despite the development of trained mobile rescue squads, cardiopulmonary collapse outside the hospital continues to carry a poor prognosis. We examined retrospectively the clinical courses of 19 consecutive coronary unit patients who had experienced prehospital cardiopulmonary resuscitation. Seven patients received basic life support from bystanders within five minutes. Cardiopulmonary resuscitation in the other 12 patients was delayed beyond five minutes pending the arrival of rescue personnel. Six of seven early-resuscitated patients survived compared with six of 12 late-resuscitated patients (P < 0.01). The early-resuscitated patients were more alert on admission and had lower pulmonary pressures and higher cardiac outputs compared to the late-resuscitated patients. The early-resuscitated patients also had less residual central nervous system and myocardial damage on discharge than the late-resuscitated patients. On follow-up, three early-resuscitated patients had returned to full-time work compared with none in the late group. Training laymen to initiate early basic life support can benefit the cardiopulmonary collapse victim.

MORE THAN 650,000 DEATHS are attributed annually to cardiovascular diseases. Those deaths which occur within 24 hours of symptom onset, defined as sudden by the American Heart Association, may exceed 300,000 annually.1,3 Approximately two-thirds of these sudden death victims die before reaching a hospital and one-third die virtually instantaneously, even before the arrival of rescue personnel.1,4,5 The majority of instantaneous deaths occur in the presence of family, friends, colleagues or bystanders.6 These people represent the only possible source of assistance in the crucial interval between collapse and the arrival of a rescue team. The immediate initiation of basic cardiopulmonary resuscitation by these bystanders before the arrival of a rescue team might increase the likelihood of the victim's recovery without residual ischemic damage.

To evaluate the potential benefit from such bystander-initiated cardiopulmonary resuscitation, we analyzed the clinical courses of patients surviving long enough to be admitted to the University of Alabama coronary care unit after prehospital cardiopulmonary collapse with resuscitation by bystanders and rescue personnel. We examined the hemodynamic parameters, serum enzyme changes, residual central nervous system deficits and ultimate return to prior activity in this selected group of both early and late-resuscitated patients. We made no attempt to define the population from which our patients were drawn nor to study victims who died before reaching our coronary unit.

Methods

Consecutive admissions to the coronary care unit (CCU) were screened retrospectively for those patients who had experienced prehospital collapse and cardiopulmonary resuscitation (CPR). Rescue calls in the city of Birmingham are answered by six specialized neighborhood rescue units manned by firemen who have qualified as Advanced Emergency Medical Technicians after a 280 hour course. Typical unit response time after being called is four minutes. The squads are physician-supervised by ECG telemetry and voice communication to our emergency ward and carry portable defibrillator units plus commonly used cardiac drugs. Patients were defibrillated at the scene and during transport by rescue personnel. Victims were transported to the nearest hospital by separate ambulance units. We reconstructed the events surrounding each rescue and resuscitation based on the emergency ward record and accounts of eye witnesses. When necessary, patients were defibrillated, monitored and treated with appropriate drugs in the emergency ward before transfer to the CCU.

All patients underwent right heart catheterization with a Swan-Ganz thermodilution catheter on admission to the CCU. Informed consent was obtained from the patient himself or an immediate family member. The catheter was left indwelling in the main pulmonary artery for 24 to 48 hours of hemodynamic monitoring. After an initial calibra-
tion against the pulmonary capillary wedge pressure, the pulmonary artery end-diastolic pressure (PAEDP) was recorded hourly by a bedside computerized system. Thermodynamic cardiac outputs were obtained from 12-hour intervals after admission. Laboratory studies included serial electrocardiograms, serum glutamic oxaloacetic transaminase (SGOT) and total creatine kinase (CK). Follow-up coronary and left ventricular angiography was performed in all but two survivors, usually within 30 days after admission, in accordance with ongoing studies of the long-term prognosis and management of coronary disease following acute myocardial infarction. The neurologic evaluation of these patients consisted of serial clinical assessments of state of consciousness, intellectual function and memory. Electroencephalograms were obtained in patients comatose for more than three days. Patients were judged to be free of residual central nervous system (CNS) impairment on discharge if their intellect and memory matched their pre-resuscitation performance. Follow-up status was evaluated approximately six weeks following discharge by examining outpatient clinic records. Group differences were evaluated using the non-paired t and chi square tests.

Results

Nineteen patients treated during a 17-month period from April 1975 through August 1976 met the criteria of prehospital collapse with resuscitation and survival long enough to be admitted to the coronary care unit. Seven had received basic life support within five minutes from bystanders (early) whereas the remaining 12 patients had experienced a delay in the initiation of cardiopulmonary resuscitation beyond five minutes pending the arrival of a rescue team (late).

Clinical Findings

The clinical findings in the two groups are summarized in figures 1 and 2. The mean ages were similar and males predominated. Seventy-one percent of early patients and 58% of late patients gave a history of prior documented coronary artery disease, acute myocardial infarction or angina. About one-half of the patients, 43% early and 50% late, showed evidence of a new acute myocardial infarction on their admission electrocardiograms. Four patients from the late group had a flail chest or simple rib fractures, whereas none of the early patients sustained fractures. Eleven of the 12 late patients were comatose on admission as opposed to two of seven in the early group. All early patients were found to have severe coronary artery disease, six at catheterization and one at postmortem examination. The three late patients who came to necropsy were found to have severe coronary disease as were three of four late survivors at follow-up catheterization. The one patient in the late group without evidence of coronary artery disease was a 55-year-old man with a history of a cardiac murmur who was found at catheterization to have normal coronary arteries and a 150 mm Hg gradient across the aortic valve.

Figure 2 shows that the admission systolic blood pressures of 122 mm Hg in the early patients and 108 mm Hg in the late patients were not significantly different. However, the initial pulmonary artery end-diastolic pressures were significantly greater in the late-resuscitated patients (mean 29 mm Hg) than in the early-resuscitated patients (mean 15 mm Hg) (P < 0.01). The initial cardiac outputs were lower in the late group (mean 2.2 L/min/m²) than in the early group (mean 3.1 L/min/m²) (P < 0.05). The mean peak SGOT and total creatine kinase were greater in the late-resuscitated patients. Late-resuscitated survivors spent an average of 53 hours on a ventilator compared with two hours in the early survivors (P < 0.01). Late survivors were hospitalized an average of 31 days compared with 19 days for the early group.

ECG Data

ECG data obtained from rescue squad telemetry transmissions and from the initial emergency ward electrocardiograms documented ventricular fibrillation or ventricular tachycardia in 17 of the 19 patients. The initial ECG from one patient unconscious for an uncertain length of time

![CLINICAL FINDINGS](image)

**Figure 1.** Clinical findings of the early and late resuscitated groups. Coma on admission and rib fractures were more common in the late group.

![CLINICAL FINDINGS](image)

**Figure 2.** Further clinical findings of the early and late resuscitated groups. Hemodynamic and laboratory data suggest greater myocardial dysfunction and ischemic injury in the late group.
showed a very slow idioventricular rhythm which reverted to ventricular fibrillation after epinephrine and was then defibrillated to a stable sinus rhythm. Another patient who had an apparent cardiac arrest according to witnesses and who died after two days in the coronary unit with severe CNS damage, had atrial fibrillation with a rapid ventricular response on his initial electrocardiogram.

Initiation of CPR

The interval between the onset of cardiopulmonary collapse and the initiation of CPR was estimated from accounts obtained in the emergency ward without any direct corroboration from the fire rescue units. The time from collapse to the arrival of the rescue team was reportedly five minutes or greater in 17 of the 19 resuscitations. In two instances, the rescue squad was not called. One of these patients was found in her car near the emergency ward entrance and was carried in by pedestrians who did not initiate CPR. Another patient experienced ventricular tachycardia during a graded exercise test outside of the hospital and was immediately defibrillated by the attending physician without the need for chest compression or rescue squad assistance.

Bystander Resuscitations

The circumstances related to each of the bystander resuscitations are summarized in table 1. Two of the seven resuscitations occurred at home, two in restaurants, one at a convention, one on a downtown street and one during a graded exercise test conducted in a physician's office outside the hospital. Four of the bystanders were medical personnel, the remaining three laymen. One of the latter was an executive who had recently completed an American Heart Association course in basic cardiopulmonary resuscitation. The other two laymen, a physical education instructor and a policeman, were formally trained and practiced in CPR. The single death in this group occurred in a 71-year-old woman with a large myocardial infarction in whom cardiopulmonary resuscitation was begun within five minutes at home by a registered nurse who was a family member. This patient died two days after admission and necropsy was denied.

Discharge and Follow-up Status

Patient status on discharge in shown in figure 3. Five of seven patients resuscitated within five minutes by bystanders were judged to have no CNS impairment on discharge, one had impaired memory, and one died. Among the 12 patients whose resuscitation was delayed greater than five minutes, six died, five were judged to have CNS impairment and one was felt to be unchanged from his pre-arrest status. This difference in mortality and CNS impairment was significant at the 0.01 level using the chi square test.

The last column in table 1 summarizes the follow-up status of the early-resuscitated patients. Five of the seven early patients returned to their pre-arrest neurological status including three who returned to full-time work. Three of the seven early patients went on to successful coronary saphenous vein bypass surgery. One patient had a history of prior coronary bypass surgery. Another patient has on his own initiative completed an American Heart Association training course in basic cardiopulmonary resuscitation and has expressed a desire to become a CPR instructor.

Discussion

In this study of selected patients reaching our coronary care unit, those whose resuscitation was initiated by bystanders within five minutes of prehospital cardiopulmonary collapse fared much better than patients whose resuscitation was delayed beyond five minutes pending the arrival of a trained rescue team. The early-resuscitated patients exhibited less hemodynamic disturbance and CNS dysfunction than late-resuscitated patients. A greater proportion of bystander-resuscitated patients sur-
vived to be discharged from the hospital and most were able to return to their pre-arrest activities.

Sudden death from coronary artery disease has been a recognized public health concern for decades. Ventricular fibrillation leading to asystole is the usual proximate cause of these rapid deaths, although uncertainty remains about the role of bradycardiac rhythms in the sudden death syndrome. At postmortem examination, extensive coronary artery disease is usually demonstrable, although often without evidence of recent myocardial necrosis. Of course, diseases other than atherosclerosis, such as aortic stenosis, cardiomyopathy or massive pulmonary thromboembolism, may precipitate sudden or instantaneous death, although less commonly. In our study group, all patients had severe coronary artery disease at catheterization or necropsy except one man with severe aortic stenosis. On the other hand, only about one-half of the patients in each group had evidence of a concomitant acute myocardial infarction.

The introduction of external electrical defibrillation by Zoll in 1956 and of closed chest cardiac massage by Kouwenhoven et al. in 1960 represent dramatic advances in the management of cardiopulmonary collapse. However, the dissemination of the cardiac compression technique beyond the immediate medical community has been a matter of debate since its inception. CPR techniques were readily incorporated into the hospital setting in specialized units designed for surveillance of dysrythmias and cardiopulmonary collapse in the immediate postinfarction period. The now ubiquitous coronary care unit (CCU) has reduced the mortality of hospitalized myocardial infarction patients by up to 50% in some series and is generally considered worth its high cost in personnel and equipment. Further reductions in mortality may occur in the future with the introduction of hemodynamic monitoring and control of infarct size. Such measures are irrelevant, however, to the 200,000 cardiopulmonary collapse victims annually who never reach a hospital.

Mobile Rescue Teams

A logical extension of the CCU concept has been the trained rescue squad or mobile CCU introduced by Pantridge in Belfast. During the 1960s, nonprofessional paramedics were successfully trained in CPR techniques and began manning rescue units. Paramedic training requirements have now become quite rigorous and the number and sophistication of rescue units has increased dramatically. In most instances these specialized units may be expected to reach a victim within five minutes of being called and even faster in some communities. In the management of unexpected ventricular dysrythmias, however, even these rapid response times may be too slow, especially when there is a delay in placing the rescue call. The ultimate effectiveness of mobile rescue squads in the management of instantaneous collapse is particularly difficult to assess. Early experience in the Seattle prehospital care program suggested a salvage rate of one in 10 patients recently improving to one in four. This may be due partly to an increase in lay CPR education programs in the Seattle area. Considerable variability in the salvage rate may exist from one community to another. As with hospital-based CCUs, mobile units can be expensive, necessitating continuing evaluation of their cost effectiveness.

Delay in initiating CPR has predictable deleterious effects on the likelihood and quality of survival. Varying response times to emergency calls plus delays in initiating the rescue call are major causes of variability in mobile unit effectiveness. Mortality increases with greater delay. An early study showed a high rate of survival in patients resuscitated within four minutes of collapse as opposed to only 5% survival in those whose CPR was delayed more than four minutes. A recent study corroborated these findings and also suggested that patients resuscitated after five minutes had more residual CNS impairment. In another series of 86 patients resuscitated within four minutes, 60% survived. In our selected group of resuscitated patients reaching the CCU, six of the seven who received CPR within five minutes survived and five had no residual CNS impairment, whereas six of the 12 experiencing delayed CPR survived and only one had no residual CNS impairment.

Those victims dying in the minutes before the arrival of a rescue unit have generally been considered irretrievable. Organized medical care simply takes too long to alert, move and apply. Attention in this area has been directed more toward risk factor modification in hopes of averting future events of the same type. CCU experience suggests, however, that even rudimentary resuscitative efforts may facilitate dramatic recovery when applied correctly and smoothly immediately after collapse from a ventricular dysrythmia. Long-term prognosis of post myocardial infarction patients may be no worse than the patient with an infarction and no arrhythmias. People resuscitated fortuitously within very brief periods after observed collapse outside the hospital may also do well, although their prognosis may be less favorable when dysrythmias occur without concomitant myocardial infarction. Myocardial infarctions were equally represented in our two groups.

Lay CPR Instruction

Teaching external cardiac compression to nonprofessional, nonparamedic laymen has been suggested as a means of salvaging victims of prehospital collapse. Deterrents to the implementation of this concept include its cost in teaching manpower and time, the uncertainty that laymen will retain motivation and proficiency after training ceases, and the recognized complications of incorrectly applied chest compression. The CPR training process is unavoidably strenuous and time consuming, requiring considerable effort on the part of student and teacher alike. Community coordinated programs seem to be a prerequisite for successful training as exemplified by those in Seattle and Marin County. The goal is a larger pool of CPR trained individuals in the community. Particularly accessible groups appear to be high school and college students, blue and white collar workers, sports enthusiasts, members of community organizations, and relatives of patients with known heart disease or hypertension.

The quality of performance of laymen once trained in CPR but unpracticed may be disappointingly poor, however. Continuing practice in addition to the initial training course appears to be crucial in maintaining proficiency. Our successful lay bystanders tended to be
practiced (the gym teacher and the policeman) or recently trained (the executive). None of them were nonpracticed laymen whose CPR performance might be most suspect. On the other hand, one recent study has suggested that three out of four lay resuscitations appeared to have been technically adequate and were associated with a favorable outcome. Bystander participation has varied greatly in different studies. Pantridge found in Belfast that two-thirds of resuscitations were lay-initiated whereas other studies have reported much lower lay participation on the order of 12%. Lay participation in Seattle has increased from 5% to 20% over four years in association with community sponsored CPR training programs. In the Birmingham area, a lay CPR training program has been sponsored by the American Heart Association, Alabama affiliate. In our study, approximately one-third of the resuscitations we evaluated were lay-initiated.

There is considerable evidence to suggest that incorrectly applied CPR, especially external massage, may cause important complications when poorly trained or unpracticed laymen are involved. Serious potential problems include rib fractures, flail chest, spleen or liver laceration, pneumothorax and hemopericardium, among others. In our patients, fractured ribs and flail chest were the most common complications of prehospital CPR, occurring exclusively in the group whose CPR was delayed. We speculate that this may have been due to more prolonged CPR in this group rather than to any inadequacy of chest compression technique.

Our experience of improved morbidity and mortality in bystander resuscitated victims has recently been corroborated by Lund and Skulberg. Among their 631 victims of prehospital cardiac arrest, 75 received lay CPR initially with 36% surviving. Only 8% survived when CPR was delayed pending the arrival of a trained ambulance team. We have carried this further by demonstrating that late-resuscitated patients exhibit higher pulmonary artery pressures and lower thermocardiogram indices, suggesting more left ventricular dysfunction in this group than in early-resuscitated patients. Greater SGOT and CK enzyme elevations in the late-resuscitated group suggest more extensive ischemic muscle injury, probably skeletal as well as myocardial. Creatine kinase isoenzyme determinations would have been helpful to define the extent of myocardial damage alone, but this test was unavailable at the initiation of this study. CNS ischemic injury was also greater in the late-resuscitated patients judging by the higher incidence of coma, ventilator dependency and residual intellectual and memory impairment.

Thus in prehospital cardiopulmonary collapse victims surviving to be admitted to our CCU, bystander-initiated basic life support was associated with a more favorable outcome than CPR delayed until the arrival of a trained rescue team. Although four of our seven bystanders were medical professionals rather than laymen, we nevertheless feel that these clinical and laboratory data support the concept of lay CPR training programs.

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D P Copley, J A Mantle, W J Rogers, R O Russell, Jr and C E Rackley

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