Prehospital Care of Acute Myocardial Infarction

By Paul N. Yu, M.D.

SUMMARY
It has been estimated recently that half of deaths among the patients with acute myocardial infarction occur before they ever reach the hospital for definitive medical care. One of the major reasons for the high incidence of death was attributed to delays in reaching medical care, involving patients themselves, physicians, transportation, and receiving areas of the hospital. In order to reduce this high mortality substantially we should focus our attention on the prehospital care of this disease, which may include several major approaches.

A. To shorten the delay in securing medical care:
   1. Public education, with emphasis on the early warning symptoms and signs of acute myocardial infarction, and the need and importance of seeking early medical care, with special attention directed toward the high-risk coronary patients.
   2. Professional education.
   3. Mechanisms to direct and/or bring patients with suspected or proven acute myocardial infarction promptly to the system of medical care with special emphasis on the utilization of a telephone information center and provision of rapid transportation.

B. Establishment of emergency life-support stations for screening, monitoring, and early stabilization of cardiac arrhythmias:
   1. Fixed.
      a. Emergency department of hospitals, preferably with an attached precoronary care area.
      b. Areas where many employees are working on weekdays.
      c. Areas where many people move in and out from day to day.
      d. Areas where there is periodic concentration of mass population.
   2. Mobile.
      a. Mobile coronary care unit.
      b. Mobile intensive care unit.

C. Prevention of sudden death:
   2. Development of techniques for early diagnosis and management of acute myocardial infarction prior to inception of symptoms.
   3. Identification of individuals prone to sudden death.
   4. Preventive measures directed toward the individuals prone to sudden death.
      a. Effective control of risk factors.
      b. Intermittent or periodic electrocardiographic monitoring in these individuals.
      c. Long-term antiarrhythmic therapy for these individuals.
      d. Possibility of implanting an automatic defibrillator in patients with previous myocardial infarction or in those recovered from ventricular fibrillation.
   5. Early administration of antiarrhythmic drugs in patients with suspected or proven acute myocardial infarction.

Coronary artery disease is the leading cause of death in this country. For a number of years, emphasis was on the in-hospital care of patients with acute myocardial infarction, a trend that was strengthened...
by the inception of coronary care units. In the past several years, however, increasing attention has been focused on the prehospital phase;1-10 recent studies indicate that two thirds of the deaths from acute myocardial infarction occur outside the hospital, and nearly one half of these deaths are sudden and unexpected, occurring within 2 hours after the onset of symptoms.11-17 The cause of death in the vast majority of patients was presumed to be ventricular fibrillation.1, 2, 7, 18-21 which was found to be 10 to 20 times more likely to develop during the first 4 hours after onset than it was between 4 and 24 hours after onset. It was further observed that patients with known coronary artery disease and with certain high-risk factors may have a greater chance of dying suddenly.7, 11, 14-17, 22-27

Many lives have already been saved outside the hospital by mobile coronary care units (MCCU) and mobile intensive care units (MICU); they have made possible the prompt institution of prophylactic and resuscitative measures for the prevention and treatment of the life-threatening cardiac arrhythmias that occur during the early stage of acute myocardial infarction.1, 5, 28-36 Furthermore, preliminary results obtained from a small number of patients indicate that the hospital mortality rate of those who were treated in the first 2 hours after onset of symptoms was impressively lower than those who received care after more than 2 hours of chest pain.1 This initial observation was subsequently confirmed by other works.35, 36 It would seem to be of paramount importance, therefore, to emphasize prompt medical care during this critical prehospital phase.

The term "prehospital care" is defined as the preventive and therapeutic measures rendered to patients with suspected or proven acute myocardial infarction during the interval between the onset of the disease and their arrival at a hospital equipped to provide definitive medical care. Several approaches to the delivery of early care are currently being studied. Different communities will probably find only certain of these approaches applicable, depending upon their resources, manpower, facilities, and capabilities. The three major problems of prehospital care that must be overcome by these approaches are delays in reaching medical care, unavailability of local emergency facilities, and lack of data on the mechanisms of and possible preventive measures against sudden death.

A. To Shorten the Delay in Securing Medical Care

The delay in instituting definitive medical care to a patient with suspected or proven acute myocardial infarction may be attributable to several major factors: the disease itself, the patient, the physician, transportation, and receiving areas.7, 8, 10, 16, 31, 37-39

Delay due to the Disease Itself. The first delay in some cases takes place between the onset of acute myocardial infarction and the development of symptoms that may not be appreciated or recognized by the patient himself. In a small number of patients with so-called silent myocardial infarction, symptoms are absent or so mild as to be unrecognizable, and in some patients death is so sudden that symptoms must have been short-lived or even absent.

Patient Factors. In most cases, when symptoms are experienced, delay in seeking medical help is the result of the patient's own indecision, which may be related to: (a) lack of information concerning the significance and importance of the symptoms; (b) fear and denial that the chest pain may actually signal a heart attack; (c) misinterpretation of the chest pain as a symptom of indigestion or disorder of another organ system; (d) reluctance to call his physician or a hospital during an inconvenient time such as night or weekend; or (e) lack of encouragement or assistance from his family members, friends, or co-workers in seeking medical help.

Physician Factors. In one study of 100 randomly selected patients, it was found that physicians contributed to patient delay in 12% of the cases.38 Certain physicians may not be familiar with the logistics and community facilities provided for prompt medical care of their patients. A small number of physicians may think that there is little they can do for...
the patient with acute myocardial infarction.

Transportation Factors. Even when the diagnosis of acute myocardial infarction is strongly suspected and the patient is urged to go to a hospital, there may be a delay in transportation. This is true both in cities where traffic is congested and in rural areas where medical transportation facilities are inadequate.

Receiving-Area Problems. Because of a shortage of professional personnel or because of a normal electrocardiogram on arrival, patients with suspected acute myocardial infarction may be left unattended in emergency rooms for several hours.

To help alleviate delay in seeking immediate medical care, attention should be directed toward public and professional educational programs and toward mechanisms to direct or bring patients to early care.

1. Public educational programs should be carefully planned, organized, and coordinated at the community level. They may include:

   (a) Publicity regarding the symptoms of acute myocardial infarction through distribution of special pamphlets, television and radio, articles in newspapers, public meetings, etc. The American Heart Association has recently published a flyer describing warning signs and steps to take to obtain prompt medical care.

   (b) Public information regarding the need and importance of immediate care for patients with suspected or proven acute myocardial infarction, particularly monitoring, surveillance, and early stabilization of cardiac rhythm. The public should be impressed with the fact that the first few hours after the onset of symptoms are critical and that lives can be saved by early and appropriate therapy.

   (c) Special instructions to high-risk coronary patients concerning the urgency of getting immediate care when they develop acute retrosternal pressure or pain of prolonged duration. It may be desirable to educate also the patient's relatives, close friends, and fellow workers who will immediately call for help whenever the patient's symptoms are suggestive of an attack of acute myocardial infarction. Among high-risk coronary patients are those who have had a previous myocardial infarction, those with recent onset, sudden recurrence, or crescendo type of angina pectoris, and those with hypertension, hyperlipidemia, history of cigarette smoking, diabetes mellitus, obesity, or electrocardiographic evidence of left ventricular hypertrophy.22, 27, 40-43

2. Professional educational programs should stress the following areas: (a) Identification

HEART ATTACK? THESE FACTS COULD SAVE YOUR LIFE

Thousands of Americans die of heart attack each year because they don't know the symptoms and wait too long to get medical care. Minutes can count when heart attack strikes. Act promptly. Delay may cost your life.

Know These Warnings

Symptoms vary...but these are the usual warnings of heart attack:

- Prolonged heavy pressure or squeezing pain in the center of chest, behind the breastbone.
- Pain may spread to the shoulder, arm, neck or jaw.
- The pain or discomfort is often accompanied by sweating. Nausea, vomiting and shortness of breath may also occur.
- Sometimes these symptoms subside and then return. Don't wait. Act immediately.

What To Do

1. Call your doctor and carefully describe your symptoms.
2. If your doctor is not immediately available, get to a hospital emergency room at once.
   The decision to obtain help should not be left to the patient's judgment alone. It is also the responsibility of the wife, husband, relative or friend.
of high-risk coronary patients. (b) Recognition of symptoms and signs of acute myocardial infarction with emphasis on presence of prodromata.44-47 (c) The importance and urgency for prompt care of patients with suggestive symptoms and signs. (d) Knowledge of appropriate medications for the treatment of cardiac arrhythmias in emergency situations. (e) Capability in cardiopulmonary resuscitation. (f) Familiarity with the community facilities for patient referral. (g) Patient education regarding the importance of getting immediate care on the development of suggestive symptoms and the source of such care—hospital emergency room, coronary care ambulance, or a local fixed life-support station. A selective group of patients who have had previous history of myocardial infarction may be given the telephone number of the ambulance service, and they or their relatives be allowed to send for the ambulance if they develop suggestive symptoms of another attack of myocardial infarction.

Continuing professional education and up-to-date instruction concerning recognition of the disease and how patients may be directed to prompt medical care should also be available to other medical and allied health personnel, i.e. dentists and nurses, especially visiting or industrial nurses. Postgraduate courses, seminars, conferences, bedside instruction, and demonstration may be arranged, sponsored, and/or coordinated by Regional Medical Programs, the American Heart Association and its affiliates, the American College of Cardiology, university medical centers and affiliated hospitals, community hospitals, and various professional societies and organizations.

3. Mechanisms to direct or bring the patient to early medical care should include: (a) Establishment of telephone information centers in various communities where patients with suggestive symptoms may call for advice by a professional person regarding local resources and facilities for immediate medical care. At the same time, the telephone information center may send for ambulances or other means of rapid transportation. Initially, this kind of service may be purely local, but in the near future a national telephone network with a uniform number may be feasible. (b) Development of a rapid and effective transportation system with ambulances, private cars, and, in some rural areas, helicopters so that patients with suspected or proven myocardial infarction may be brought to medical care without delay.

B. Establishment of Emergency Life-Support Stations

1. Fixed emergency life-support stations could utilize the following facilities.

(a) The most appropriate and logical fixed emergency life-support station is the hospital emergency area. Each hospital should have a definite policy for emergency care of patients with suspected acute myocardial infarction, including systems for prompt identification of these patients, for initiating continuous electrocardiographic monitoring even before obtaining a detailed medical history, and for providing continuous surveillance until a definitive decision on management is made. Physicians and nurses should have the training and experience to recognize serious brady- and tachyarrhythmias, to institute appropriate antiarrhythmic drugs, and to initiate defibrillation. It is also advisable that a number of qualified allied health personnel be trained to assist. In addition, consideration should be given to the feasibility of providing facilities for emergency cardiac pacing.

It has been suggested that a “precoronary care area” (PCA), designed to triage for early symptoms and signs of acute myocardial infarction, may be established in some hospitals or neighborhood health centers. Such a PCA may be used to screen, monitor, and treat patients who arrive either on their own or on referral. The patients may be kept in the PCA for a relatively short time until a definitive diagnosis is made. The PCA should be equipped with appropriate drugs and defibrillator for effective management of life-threatening cardiac arrhythmias during the first few hours of the illness. If there is strong suspicion that the patient has an acute
A 54-year-old man arrived at the emergency room of the University of Rochester Medical Center at 8:30 PM. Before his arrival he experienced severe squeezing retrosternal pain and profuse sweating for about 1 hour. The patient was immediately monitored. At 8:36 PM a 12-lead electrocardiogram was taken and showed some elevation of S-T segment in leads V₁-V₄ (panel A). Four minutes later, while the patient was being interviewed by the house staff, he suddenly developed ventricular fibrillation (panel B), which was successfully reverted to sinus rhythm by a precordial countershock. At 9 PM another 12-lead electrocardiogram was recorded, and the changes were similar to those recorded at 8:36 PM (panel C). Subsequently, however, serial electrocardiograms and serum enzyme changes were consistent with the diagnosis of acute anteroseptal myocardial infarction.

In the near future the emergency department of all hospitals or the PCA in many may become a major indispensable component of prehospital care.

In addition to the emergency area of the hospitals, fixed life-support stations should also be considered for other locations.

(b) Factories, industrial plants, or large office buildings where a large number of employees work may have stations set up in the medical dispensaries where nurses and possibly physicians are always available during working hours.

Physicians and nurses in teaching or large community hospitals have frequently had to perform defibrillation in the emergency department (fig. 1). It is anticipated that in the near future the emergency department of all hospitals or the PCA in many may become a major indispensable component of prehospital care.
(c) Metropolitan airports and large railroad stations and bus terminals where many people congregate daily, particularly between 7 AM and 7 PM could also be used.

(d) Sport stadiums and convention halls or other special locations, where there is a periodic concentration of mass population during certain days or seasons, might have a special room or vehicle to be used as an emergency life-support station and staffed by nurses and allied health personnel.

In all three areas, physicians may not be in attendance all the time, but appropriate arrangements should be made for the availability of cardiac consultations through telephone or two-way radio transmission. In these fixed life-support stations, facilities should be provided for continuous monitoring of electrocardiograms, for effective management of cardiac arrhythmias, and for resuscitative measures such as defibrillation. The major function of these stations is to insure stabilization of cardiac arrhythmia at the very inception of a major coronary attack. When stability is achieved, the patient should be transferred in an ambulance to a nearby hospital for definitive care. Prompt transfer of patients should be arranged if there are manifestations of serious complications such as cardiogenic shock, profound cardiac failure, or progressive heart block.

Examples of such fixed life-support stations are included in the dispensaries of a large Rochester, New York, industrial firm which employs more than 45,000 workers. A prehospital program was initiated under the auspices of the Myocardial Infarction Research Unit (MIRU) established at the University of Rochester Medical Center and supported by the National Heart and Lung Institute. This program has been in operation for more than 2 years.49 An employee who develops chest discomfort may seek medical help at the medical dispensary of any one of the three plants. Physicians and nurses are in constant attendance during the working hours. If the employee's symptoms are suggestive of acute myocardial infarction, a 12-lead electrocardiogram is recorded, and continuous monitoring of his electrocardiogram is initiated on an oscilloscope as well as by a Holter-Avionic recorder. Blood and urine samples are collected for specific biochemical examinations. Drugs are administered for cardiac arrhythmia, and defibrillation is instituted if indicated. Only after his condition is well stabilized is the employee transferred by ambulance to one of the city's six community hospitals where Avionic tapes are recovered from the patients for further screening and identification of cardiac arrhythmias.

While quantitative analysis of the data is not yet completed, preliminary information may be of some interest (Moss AJ, Goldstein S, Green WA: Unpublished data). Up to the end of March, 1971, 33 employees included in the prehospital program were diagnosed as having definite acute myocardial infarction. Of these 33 patients 20 arrived at the dispensary within 1 hour after the onset of their symptoms. Most patients apparently knew that they were having a heart attack but rationalized away their need for early medical care. Denial has not appeared to be as significant a factor.

Ventricular premature contractions (VPCs) were observed in over 70% of the patients during the first 2 hours of Avionic tape recording. Twelve patients developed major ventricular tachyarrhythmias in the first 24 hours of their illness, including two with ventricular fibrillation and three with ventricular tachycardia. One patient who developed ventricular fibrillation upon arrival at the dispensary was successfully resuscitated. In general, patients with major ventricular tachyarrhythmias were found to have higher blood cortisol levels and more frequent closely coupled VPCs than those without tachyarrhythmias.

Since most large factories or industrial firms have medical dispensaries staffed with nursing and allied health personnel, this type of fixed emergency life-support station can be set up with minimal additional cost and manpower. Its availability may encourage individuals to seek early medical care, thus shortening the delay caused by the patient's own indecision.

*Circulation, Volume XLV, January 1972*
and saving time spent in calling his physician. Furthermore, utilization of fixed life-support stations outside the hospitals will help relieve overburdened hospital emergency areas.

It should be reemphasized that the major function of these stations is to stabilize the patient's condition, particularly in terms of prophylactic and therapeutic management of cardiac arrhythmias. As soon as his condition is stable, he should be referred to a coronary care unit for definitive care.

2. Mobile life-support stations are most frequently vehicles or ambulances specially designed and equipped for emergency care of patients with acute cardiac conditions, called mobile coronary care units (MCCU). They are usually staffed with physicians, nurses, and/or allied health personnel. First reported in Russia and in Belfast, Ireland, their function and operation in Belfast have been described by Pantridge and his associates.\(^1\)\(^-\)\(^5\) They found a high instance of ventricular fibrillation during the first 4 hours of onset of symptoms. In about half of the patients a diagnosis of definite myocardial infarction was established. In their more recent experiences, 78% of the patients were reached within 15 minutes of their calls. They were able to resuscitate successfully nine of 15 patients who developed ventricular fibrillation within 4 hours after the onset of their symptoms, all of whom left the hospital alive. Of more than 300 patients attended in a 15-month period, no patient died in transit from the MCCU to the hospital. This was in contrast to a pre-MCCU study of coronary deaths in the same city over a period of 1 year (1965-66) during which almost 25% of the patients brought to the hospital were dead on arrival.\(^3\)\(^-\)\(^15\) It would appear that the operation of MCCU has been a successful and rewarding experience in Belfast, Ireland. In this country, Grace, Warren, Cobb, and their respective associates have reported their extensive experiences in MCCU operation.\(^20,\)\(^31,\)\(^32,\)\(^35,\)\(^36\)

It should be pointed out that one of the major purposes of establishing MCCUs in a few selected cities was to investigate the feasibility, scientific merits, and effectiveness of their operation. It was essential, therefore, to have professional personnel and optimal equipment on board for intensive and in-depth studies. Thus, the high cost of operating these mobile units in the initial stage may be largely attributed to the highly sophisticated equipment and use of professional personnel. As more experience has been accumulated, there is now a trend to staff these units with allied health personnel only, with portable monitoring and resuscitative equipment, and with telemetry.\(^34,\)\(^50\) After adequate training, allied health personnel should be able to monitor the patients and, under physician guidance, institute appropriate therapeutic and resuscitative measures.

At the time of this writing, vehicles or ambulances staffed and equipped for responding to emergency calls are in operation in 26 cities. Some may be considered MCCU while others are more properly designated as mobile intensive care units (MICU). In general, MCCUs are more fully equipped, are often staffed with physicians and nurses, and answer calls related to cardiac cases only, whereas MICUs have less elaborate equipment, carry allied health personnel only, and answer all emergency calls. The various features of the MCCU and MICU operated in 26 cities are presented in table 1. Their operation in seven of these cities is being supported by Regional Medical Programs (RMP). The results of five RMP-supported MCCUs are summarized in table 2.

One of the MICUs is now in operation at the Harbor General Hospital, Torrance, California. Unique features related to its operation may be summarized as follows (Criley JM, Lewis AJ: Personal communication): (1) Existing emergency health delivery system and manpower (Los Angeles City and County firemen) are used; firemen are certified under the Wedworth-Townsend Paramedic Act after passing a comprehensive examination. (2) The unit responds to all types of emergencies, not merely cardiac, and as a result of this broad use of facilities many patients with
unsuspected significant cardiac problems are discovered. (3) Firemen treat patients under remote telemetric supervision by a physician. They are permitted to defibrillate, initiate intravenous infusion, and administer six classes of drugs. The consulting physician is a resident in internal medicine assigned to the CCU of the Harbor General Hospital. He can manage patients in the MCCU without leaving the hospital. (4) All equipment is portable and battery-operated, and thus can be hand-carried to the scene to stabilize the patient before transport to the hospital. (5) Existing conventional ambulances are used to transport patients, and additional portable emergency equipment converts these vehicles into temporary MICUs.

There has been an average of 65 calls per month in the past 17 months. In approximately 20% of these calls, significant cardiac problems have been observed. Cardiopulmonary resuscitation has been necessary in approximately 8% of the cases, and medications necessary in 13%. The average response time is 5.6 minutes from receipt of call to the unit’s arrival at the scene.

Many patients who developed ventricular fibrillation in the early stage of acute myocardial infarction were successfully defibrillated and left the hospital alive. To show the effectiveness of this unit’s operation, serial electrocardiograms of a patient during ventricular fibrillation and after successful defibrillation are reproduced in figure 2.

The operation of such vehicles will answer many criticisms of MCCUs regarding cost effectiveness, shortage of professional personnel, and underutilization of equipment. It is anticipated that in the next year or two a more comprehensive report will be forthcoming concerning the operation, results, potential, and limitations of all MCCUs and MICUs in this country. Despite possible limitations, one of the by-products of a well-publicized and effective MCCU or MICU is public education regarding the life-saving aspect of early coronary care.

### Table 1

**Characteristic Features of MCCU or MICU Operated in 26 Cities**

<table>
<thead>
<tr>
<th>Features</th>
<th>No. of cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voice communication to obtain professional guidance</td>
<td>21</td>
</tr>
<tr>
<td>Portable electrocardiograph</td>
<td>22</td>
</tr>
<tr>
<td>Telemetry monitoring electrocardiograph</td>
<td>17</td>
</tr>
<tr>
<td>Portable defibrillator</td>
<td>23</td>
</tr>
<tr>
<td>Physicians on board</td>
<td>7</td>
</tr>
<tr>
<td>Nurses on board</td>
<td>13</td>
</tr>
<tr>
<td>Trained allied health or paramedical personnel</td>
<td>23</td>
</tr>
</tbody>
</table>

### Table 2

**Results of Five Mobile Coronary Care Units Supported by RMP (through 12/31/70)**

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D†</th>
<th>E</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of months of operation</td>
<td>25</td>
<td>21</td>
<td>10</td>
<td>3 1/2</td>
<td>6</td>
<td>—</td>
</tr>
<tr>
<td>No. of cases transported</td>
<td>956</td>
<td>948</td>
<td>503</td>
<td>98</td>
<td>27</td>
<td>2332</td>
</tr>
<tr>
<td>No. of acute myocardial infarctions transported</td>
<td>131</td>
<td>218]</td>
<td>236</td>
<td>36</td>
<td>12</td>
<td>633</td>
</tr>
<tr>
<td>% of cases transported that were acute myocardial infarctions</td>
<td>14</td>
<td>23]</td>
<td>47</td>
<td>37</td>
<td>44</td>
<td>25</td>
</tr>
<tr>
<td>No. of patients treated for arrhythmias</td>
<td>61</td>
<td>168</td>
<td>180</td>
<td>22</td>
<td>3</td>
<td>434</td>
</tr>
<tr>
<td>No. of patients resuscitated and brought to hospital alive</td>
<td>9</td>
<td>23</td>
<td>77</td>
<td>5</td>
<td>0</td>
<td>114</td>
</tr>
<tr>
<td>Patients resuscitated leaving hospital alive: No.</td>
<td>2</td>
<td>8</td>
<td>29</td>
<td>1</td>
<td>—</td>
<td>40</td>
</tr>
<tr>
<td>%</td>
<td>22</td>
<td>35</td>
<td>38</td>
<td>20</td>
<td>—</td>
<td>35</td>
</tr>
</tbody>
</table>

*Courtesy of Mr. Morton Robins, Chief Study and Analysis Staff, RMP Service, Health Service and Mental Health Administration, HEW.
†Data tabulated only up to June 30, 1970.
‡Estimated.
A 59-year-old man summoned the mobile intensive care unit (MICU) after he experienced severe chest pain. Marked depression of the S-T segment was demonstrated in the electrocardiogram while he was still complaining of chest pain in the MIRU. Shortly after the recording of the electrocardiogram, he developed ventricular fibrillation which was immediately reverted by a precordial countershock delivered by a paramedical personnel. Thirty seconds after the countershock an electrocardiogram showed the presence of multiple ventricular premature contractions. Following an intravenous injection of 50 mg of lidocaine and an ampul of sodium bicarbonate, the cardiac rhythm was satisfactorily stabilized. (Courtesy of Dr. J. Michael Criley, Harbor General Hospital, Torrance, California.)

Inasmuch as establishment and operation of both fixed and mobile life-support stations require the assistance of a large number of allied health personnel, it is necessary for the community involved to embark on an intensive and ongoing training program for such personnel in the emergency care of patients with acute myocardial infarction.

C. Prevention of Sudden Death

Since sudden death is a major problem in the prehospital phase of acute myocardial infarction, it seems essential to direct further study to this important and yet ill-defined event which usually occurs within the first few hours after the inception of symptoms.\textsuperscript{7, 15, 16, 51, 57} Prevention of sudden death due to coronary artery disease may be considered under two categories, primary and secondary.\textsuperscript{15} Primary prevention aims at the reduction of risk factors in order to minimize or eliminate occurrence of the disease. Unfortunately, the precise cause of atherosclerosis is still unknown, with no basic research breakthrough in sight. It is unlikely, therefore, that primary prevention may reach any degree of measurable success in the foreseeable future.
We may be able, however, to reduce morbidity and mortality through secondary prevention. Current approaches include the study of mechanisms of sudden death, development of techniques or methods in the early diagnosis and management of acute myocardial infarction, identification of individuals who are prone to sudden death, evaluation of preventive measures directed toward high-risk individuals, and early administration of antiarrhythmic drugs to patients with suspected or proven acute myocardial infarction.

1. Study of the mechanisms of sudden death is necessary because precise information concerning the mechanisms and clinical environment of sudden death is lacking. As indicated in the 1969–70 Annual Report of the Program Office of the Myocardial Infarction Research Units (MIRU) of the National Heart and Lung Institute (a public document, on file with the National Technical Information Service of the U. S. Department of Commerce, Springfield, Virginia), research in this area is being directed toward acquisition of information and insight concerning (a) external precipitating factors for myocardial infarction and sudden death; (b) physiologic and environmental settings in which they occur; (c) physiologic events that precede myocardial infarction and sudden death; (d) early physiologic consequences of acute illness; (e) pathologic changes and correlation with historical events and physiologic observations; (f) epidemiology of risk factors; (g) symptoms premonitory to impending myocardial infarction; and (h) prophylactic and early therapy to prevent myocardial infarction and sudden cardiac death.

2. Development of techniques and methods for early diagnosis and management of acute myocardial infarction prior to symptomatic onset would be worthwhile. Current diagnostic criteria depend on a typical history, evolutionary electrocardiographic changes, and serial enzyme abnormalities. By the time a patient complains of severe and prolonged chest pain, a significant degree of irreversible myocardial ischemia is probably already present. This early stage of acute myocardial infarction is a crucial period for the development of electrical instability, characterized by ventricular tachyarrhythmias. If we could develop some techniques to detect the early occurrence of the lesion prior to the inception of symptoms and institute antiarrhythmic therapy accordingly, the incidence of ventricular fibrillation and sudden death might be drastically reduced.

3. Identification of individuals prone to sudden death is another important consideration as pointed out by Sidel, Acton, and Lown: "If a population at a very high risk can be selected with a high degree of sensitivity and specificity, the cost of prevention can be reduced and effectiveness increased. With appropriate collection and analysis of data, more discriminating methods of selection may be devised, and alternative strategies can be re-evaluated." It is indeed difficult, if not impossible, to identify a group of individuals at random who are susceptible to sudden death. Furthermore, at the present time there is really no practical means for such identification. From the available information, it would seem reasonable to direct our special attention toward certain groups of individuals:

(a) Those who have already had a previous attack of myocardial infarction. In a combined series of more than 2,300 patients who died within 24 hours of onset of symptoms, 53–65% of them had a previous history of coronary artery disease and about 30% had a previous history of acute myocardial infarction.

(b) Those with recent onset, sudden recurrence, or crescendo type of angina pectoris. The incidence of sudden death among patients under any one of these three categories has been found to be higher than those with steady angina pectoris.

(c) Those patients who have multiple coronary arterial obstructions demonstrated by coronary angiogram.

(d) Those patients with coronary artery disease who exhibit cardiac arrhythmias or conduction defect. Ventricular premature contractions are the most frequently
encountered cardiac arrhythmia. These may be detected by means of a routine 12-lead electrocardiogram or more effectively with an 8–10 hour Holter-Avionic recording, or during a stress test. Conduction defect may be either bundle-branch block or A-V block.

(c) Those who have known multiple-risk factors, particularly hypertension, cigarette smoking, hyperlipidemia, diabetes mellitus, obesity, and electrocardiographic evidence of left ventricular hypertrophy. Whether changes in physical activity, psychosocial stress, or environmental factors that have been present during the few weeks preceding sudden death have any important bearing on this problem remains to be determined.

4. The following preventive measures directed toward the individuals prone to sudden death may be considered, if a patient prone to sudden death can be tentatively identified:

(a) Effective control of the common risk factors, such as treatment of hypertension, elimination of cigarette smoking, control of diabetes mellitus and hyperlipidemia, and weight reduction. More hard data should be collected in order to ascertain whether there is a significant reduction in the incidence of sudden death after successful control of these risk factors.

(b) Electrocardiographic monitoring in these patients at frequent intervals. It has been shown that development of ventricular fibrillation occurs frequently following the appearance of VPCs, although in many patients ventricular fibrillation may develop abruptly and with little warning. These VPCs are particularly important when they are frequent in number, occur in succession, are superimposed on the T wave, and originate from multiple foci. However, as pointed out by Lown et al., passive monitoring may not suffice to identify all the susceptible patients, and intermittent or continuous monitoring in a large group of the population may be too costly. He and his associates found that a standard 12-lead electrocardiogram, which is equivalent to about 1 minute of monitoring, exposed some VPCs in only 8% of patients with coronary artery disease. When monitoring was extended to 12 hours, about 62% of the patients exhibited VPCs (Lown B: Personal communication).

In a number of patients with coronary artery disease, VPCs are not demonstrated during prolonged periods of monitoring at rest, but are provoked only during stress test or in association with episodes of myocardial ischemia, as manifested by anginal symptoms. It is therefore desirable to use some simple tests, such as isometric exercise (handgrip), which may unmask the possible presence of VPCs without any harmful effects to the patients. Analog ectopic-beat detector and digital-computer programs have been recently used to automate the detection and recognition of VPCs.

(c) Long-term antiarrhythmic therapy for those individuals who have been identified as having frequent VPCs or risk factors. The appropriate program will involve the use of a suitable pharmacologic agent that is effective when administered orally, in relatively small doses, and has no side effects. Currently, several pharmacologic agents may be considered for this purpose, each with certain disadvantages, particularly regarding undesirable effects. These include procainamide, quinidine sulfate, bretylium tosylate, propranolol, and diphenylhydantoin. An ideal antiarrhythmic agent is not yet available, and further pharmacologic research in this area is urgently needed.

(d) Long-term antiarrhythmic therapy in patients who have recovered from an episode of ventricular fibrillation in the initial period of acute myocardial infarction. This group of patients may have a higher incidence of recurrent ventricular fibrillation and serious ventricular arrhythmias than the average postmyocardial-infarction patient, although several studies have demonstrated relatively

*C Oral preparation of bretylium tosylate for investigational trial has been withdrawn from the market recently.
favorable prognosis after recovery from ventricular fibrillation complicating acute myocardial infarction.\textsuperscript{77-80} Administration of prophylactic antiarrhythmic drugs may have significant impact in reducing the possible recurrence of life-threatening cardiac arrhythmias.

(c) Possibility of implanting some device that will automatically defibrillate the ventricular fibrillation as soon as the arrhythmia is initiated.\textsuperscript{81, 82} Assuming no malfunction or risk is involved, implantation of such an automatic defibrillator in patients with previous myocardial infarction or in those recovered from ventricular fibrillation may potentially be a feasible solution to the control of ventricular fibrillation and sudden death.

5. Early administration of antiarrhythmic drugs in patients with suspected or proven acute myocardial infarction may be lifesaving.

(a) Wyman has recently demonstrated the efficacy of intravenous prophylactic therapy with lidocaine or procainamide in preventing primary ventricular fibrillation (PVF) in a series of patients with acute myocardial infarction (Wyman MG; Personal communication). Before the introduction of prophylactic therapy, PVF was observed in 6\% of patients (nine of 139 cases).

Prophylactic therapy was initially directed toward those patients with frequent PVCs and subsequently given to all patients (last 148 cases), regardless of whether PVF was present or absent. Upon the arrival of patients in the emergency room, lidocaine was administered intravenously in 50 mg as a bolus, followed by 25 mg over a period of 1 min, and finally a drip of 2 mg/min for a 24-hour period. If PVCs were present and refractory to lidocaine therapy, 100 mg of procainamide was given intravenously as a slow bolus followed by a continuous drip of 2-6 mg/min for about 30 hours. The average time interval between the onset of symptoms and the prophylactic therapy was 7.1 hours. Since the introduction of intravenous prophylactic therapy, the incidence of PVF was reduced to 0.2\% (1 of 567 cases).

It would appear, therefore, that prophylactic antiarrhythmic therapy, even when initiated several hours after the onset of symptoms, may effectively reduce the incidence of ventricular fibrillation in patients with acute myocardial infarction.

(b) Self-injection of atropine or lidocaine. In a number of patients with acute myocardial infarction, bradyarrhythmia observed during the early stage of the disease not only lowers the cardiac output and systemic arterial pressure, but it also enhances the development of VPC.\textsuperscript{83, 84} When the ventricular rate is increased by administration of atropine, the likelihood of developing VPC decreases appreciably.\textsuperscript{84, 85} On the other hand, ventricular tachyarrhythmia, including frequent VPCs, may be successfully controlled by the administration of lidocaine. Intramuscular administration of this drug at a dose of 200-250 mg may raise the serum concentration to a satisfactory therapeutic level, which may be sustained over a period of 2-3 hours.\textsuperscript{86} (Dunning AJ, Sehmers MOC: Personal communication.)

Proposals have been made to study the feasibility and efficacy of intramuscular self-administration of an appropriate drug (atropine or lidocaine) by the patient at the onset of symptoms suggestive of acute myocardial infarction.\textsuperscript{9} This approach may be particularly desirable for the high-risk coronary patients, each of whom may carry in his pocket at all times two automatic injectors, one with 2 mg of atropine and one with 250 mg of lidocaine. The patient may transmit the rate and regularity of his heart beats, by means of a special device, over the telephone to his family physician or a special receiving center. If he has a slow heart rate, under 60 beats per minute, indicating either a sinus bradycardia or heart block, he will be instructed to give himself atropine. On the other hand, if his heart rate is over 60 beats per minute, especially when ectopic beats are present, he will be instructed to give himself lidocaine. This approach merits further study and deliberation because such a system brings with it the possibility of antiarrhythmic
therapy earlier than any other means suggested thus far.

Acknowledgment

I wish to express my thanks and appreciation to Drs. Donald T. Frederickson, Herbert J. Marx, and Morrison Hodges, and to Miss Jean Fitzpatrick, for their help and suggestions in the preparation of this paper. I am grateful to Mrs. Bonnie S. Hadden for her secretarial assistance.

References

9. SARNOFF SJ: A plan for reducing the prehospital mortality due to acute myocardial infarction. Carl J. Wiggers Award Lecture, Circulation Group, American Physiological Society, April 14, 1970
15. KULLER L: Sudden death in arteriosclerotic heart disease: Case for preventive medicine. Amer J Cardiol 24: 617, 1969
24. HINKLE LE, CARVER ST, STEVENS M: The frequency of asymptomatic disturbances of cardiac rhythm and conduction in middle-aged men. Amer J Cardiol 24: 629, 1969
25. CHIANG BN, PERLMAN LV, OSTRANDER LD, EPSTEIN FH: Relationship of premature
systoles to coronary heart disease and sudden
death in the Tecumseh epidemiologic study.
Ann Intern Med 70: 1159, 1969
26. Weiss AN, Jobe CL, Gordon T, Lange PL:
Relationship of premature ventricular contraction
and left ventricular hypertrophy to sudden
27. Kannel WB, Gordon T, Castella WP:
Electrocardiographic left ventricular hypertrophy
and risk of coronary artery disease: The Framingham Study.
Ann Intern Med 72: 813, 1970
28. Kernohan RJ, McGucken RB: Mobile intensive care
29. Chazov EI: First aid in myocardial infarction. In
Acute Myocardial Infarction, edited by DG Julian, MF Oliver. Edinburgh, E & S
Livingstone, 1968, p 313
Circulation 40 (suppl III): III-212, 1969
33. Cobb LA, Conn RD, Samson WE, Philbin JE:
34. Lewis AJ, Hemsler AJ, Besbout C, Chiley JM:
Experience with a paramedic mobile intensive care unit. Presented at the Annual Meeting of the American College of Physicians, March 29, 1971
35. Grace WJ: Experiences with mobile life support stations: New York City. (Abstr) Third National Conference on Coronary Care Units, Miami Beach, Florida, June 7-9, 1971, p 38
36. Warren JV: Experiences with mobile life support station: Columbus, Ohio. (Abstr) Third National Conference on Coronary Care Units, Miami Beach, Florida, June 7-9, 1971, p 40
38. Hackett TP, Cassem NH: Factors contributing to delay in responding to the signs and symptoms of acute myocardial infarction. Amer J Cardiol 24: 651, 1969
47. Hochberg HM: Characteristics and significance of prodromes of coronary care unit patients. Chest 59: 10, 1971
49. Myocardial Infarction Research Unit Annual Report, University of Rochester Medical Center, 1970
53. Sidel VW, Acton J, Lown B: Models for the

Circulation, Volume XLV, January 1972


55. WOODS RM, BARNES AR: Factors influencing immediate mortality after acute coronary occlusion. Amer Heart J 24: 4, 1942


66. WOLF M, HAMDI E, LOWN B: VPB detection by an analog computer in a CCU. In preparation


76. DAY HW, BACANER M: Use of bretylium tosylate in the management of acute myocardial infarction. Amer J Cardiol 27: 177, 1971

77. GEDDES JS, ADGEY AAJ, PANTRIDGE JF: Prognosis after recovery from ventricular fibrillation complicating ischaemic heart disease. Lancet 2: 273, 1967


80. STANNARD M, SLOMAN G: Ventricular fibrillation
in acute myocardial infarction: Prognosis following successful resuscitation. Amer Heart J 77: 573, 1969


Prehospital Care of Acute Myocardial Infarction

PAUL N. YU

Circulation. 1972;45:189-204
doi: 10.1161/01.CIR.45.1.189

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1972 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/45/1/189

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/