CHEST PAIN: PROBLEMS IN THE DIAGNOSIS OF ACUTE CARDIAC ISCHEMIA

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A true physician is a scientific scholar of human biology who practices his profession as a perceptive humanist.

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The various syndromes produced by acute cardiac ischemia present many challenges to primary care physicians and emergency physicians. Acute cardiac ischemia can present with any of three major syndromes - sudden cardiac death, acute myocardial infarction, and angina pectoris (stable or unstable). In patients with asymptomatic coronary atherosclerosis, the first symptom of acute cardiac ischemia is sudden death in about 25% of patients, acute myocardial infarction in about 45% of patients, and angina pectoris in the remainder of the patients.[1-3] A small percentage also present with heart failure. The importance of time, accuracy, and costs must permeate decision making when dealing with a patient with chest discomfort. Time also becomes a critical determinate in the outcome of cardiac arrest victims.

The critical nature of time is obvious when the patient suffers a cardiac arrest. When out-of-the-hospital cardiac arrest is examined, 93% of the long term survivors had witnessed cardiac arrests and ventricular fibrillation.[4-6] Time to defibrillation and CPR seem to be the most important determinants of survival. Figure 1 shows the importance of time in cardiac arrest victims.[7] As can be seen in this graphic, which is a composite of several different studies, time to defibrillation and time to CPR as well as time to ACLS (epinephrine) are very critical. The shorter each of these key times intervals is, the greater is the survival.

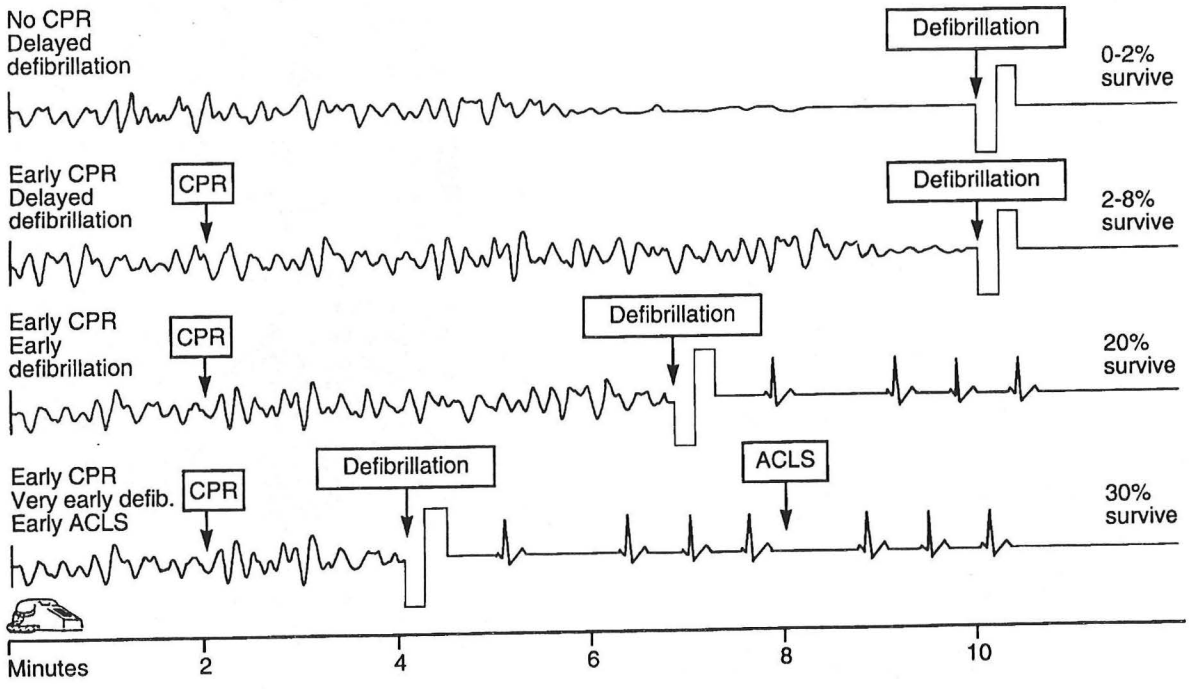
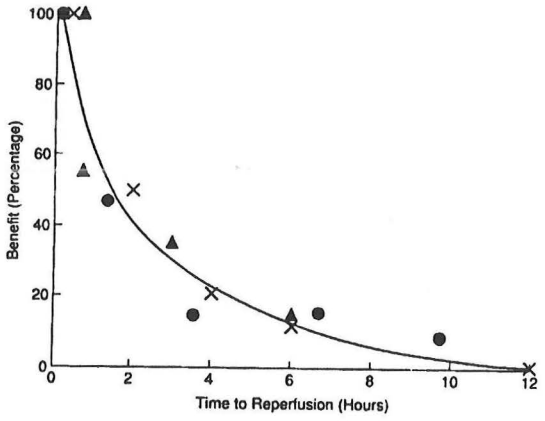


Fig 1. Survival rates are estimates of probability of survival to hospital discharge for patients with collapse and with ventricular fibrillation as initial rhythm. Estimates are based on a large number of published studies.[7]

Time is also a critical factor when dealing with a patient with an acute myocardial infarction. Obviously a patient with an acute myocardial infarction can have a cardiac arrest at any time. With

the advent of thrombolytic therapy and more recently with acute angioplasty of the occluded artery in infarcted patients, time to treatment has also become very important. Figure 2 shows a composite developed by Tiefenbrunn and Sobel[8-10] from both animal and human data after thrombolytic therapy. The animal and human thrombolytic data are very consistent, showing a very time dependent benefit curve. The major benefit is in the first two hours. The benefit of thrombolytic therapy appears to be both increased survival as well as salvage of myocardial performance. By pooling many studies Granger, Califf, and Topol[11] have shown a significant increase in ejection fraction; however, the increase in ejection fraction was small. When very early thrombolytic therapy is examined there is a marked improvement in survival and a large salvage of myocardium. The MITI trial[12] has shown that thrombolytic therapy given within 70 minutes of onset of pain can reduce mortality with acute myocardial infarction to less than 1% and can reduce the amount of tissue lost to 0-1% of muscle mass in 40% of patients and to 2-10% loss of muscle mass in another 40% of patients. Thus, very early, muscle mass can be salvaged. It appears that in the first 1-2 hours the major benefit of thrombolytic therapy is through myocardial salvage. After the first two hours, other mechanisms play a role, possibly through open artery and collateral development or remodeling (Figure 3).[8-10]



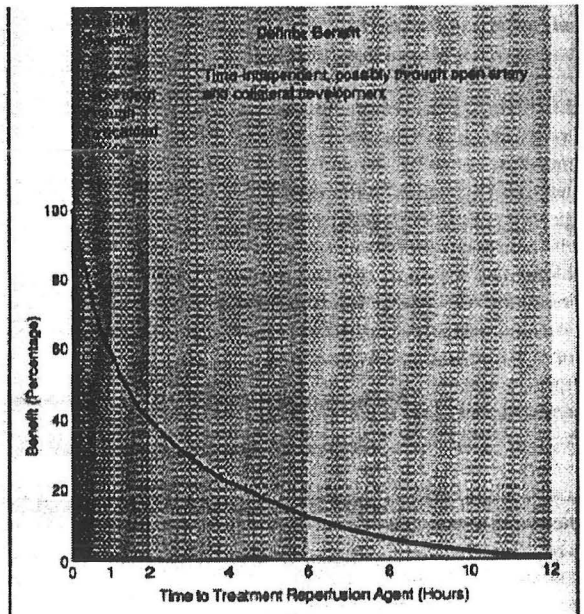
▲ Reimer et al., 1977.
Myocardial salvage related to time between interruption of coronary flow and reperfusion through release of ligature in dogs.

X Bergmann et al., 1982.
Myocardial salvage related to time between thrombotic occlusion of coronary artery to reperfusion through lysis in dogs.

● GISSI I, 1986.
Reduction in mortality related to time between onset of symptoms and treatment with intravenous streptokinase in patients with acute myocardial infarction.

This figure displays both human and animal data. For the animal studies, it shows an inverse relationship between myocardial salvage and the length of time between coronary artery occlusion and reperfusion. The concordance of the superimposed mortality reduction in patients with acute myocardial infarction from the GISSI I trial to myocardial salvage in dogs is remarkable.

Fig 2. Time to reperfusion versus benefit curve. Adapted from Tiefenbrunn and Sobel[8-10]



This figure depicts combined human and animal data and represents the time-dependent benefit anticipated, depending on the length of the interval between coronary artery occlusion and reperfusion.

Fig 3 Time to reperfusion versus degree of benefit. Adapted from Tiefenbrunn and Sobel[8-10]

Therefore, it is obvious that time to treatment is very critical when looking at many of these patients. When we closely examine the time to treatment issue, there are three major sets of interactions that determine the amount of delay to treatment. The patient must make a decision to obtain medical care. As the patient frequently asks a lay person for advice, this has been called the patient/bystander portion of the delay. Once the patient decides to obtain medical care, there is the transportation phase or emergency medical service phase if that is used. Once the patient has arrived at the hospital, there are further delays; these delays are usually in the emergency department.

There have been a number of studies that look at the time from onset of symptoms until patient arrival at the hospital. The mean arrival time in a number of studies has varied from 4.6 hours to 24 hours (Table 1).[13-19] However, it is inappropriate to use mean times. For example, if nine patients arrive at the hospital within 15 minutes and the tenth patient arrives 48 hours after onset, the mean time is five hours. Therefore, median times are more important. The median times have generally been between two and four hours with a couple of exceptions.[13,15-24] The two exceptions are the studies by Cooper,[16] which was a study of inner-city African-Americans, and the study by Hofgren,[19] which studied delays in 47 selected patients in a Swedish Hospital. When the data was analyzed to identify the number of patients who delayed more than a given time, 26% to 44% of the patients with an acute myocardial infarction delayed more than four hours.[18,24-25] Hence, the majority of patients arrive at the hospital within four hours of onset of symptoms. However, this time is still very long to achieve the maximum effectiveness of thrombolytic therapy. Also, many patients develop a cardiac arrest within this delay time.

Table 1. Delay Time from Onset of Symptoms until Hospital Arrival

Reference	N	Mean (hours)	Median (hours)
Hackett, 1969[13]	100	10.6	4
Moss, 1969[14]	64	4.6	-
Moss, 1970[20]	160	-	3.5
Simon, 1972[21]	160	-	2.75
Schroeder, 1978[15]	211	7.6	3.5
Alonzo, 1986[22]	1102	-	2.2
Cooper, 1986[16]	111	21-24	6.4
Turi, 1986[23]	778	-	2
Rawles, 1988[17]	450	10	2
Wielgosz, 1988[18]	201	7.5	3.2
Hofgren, 1988[19]	47	19.6	4.8
Leitch, 1989[24]	100	-	2

Unstable angina pectoris and recent onset angina pectoris may also be time dependent emergency situations; however, there is little information to clearly identify the importance of time. A few patients with unstable angina pectoris go on to have an acute myocardial infarction or sudden death. A few remain unstable. Most patients with unstable angina quickly quiet down. Though it is our

general feeling that time is critical in patients with unstable angina pectoris, this can not be documented.

When you are dealing with chest pain syndromes, two other factors become very important - accuracy and costs. For every 12-15 patients who present to the emergency department or the emergency system with chest pain, only one has an acute myocardial infarction and another one has acute cardiac ischemia without myocardial infarction.[12,26] Because only two patients out of 12-15 have significant disease, it is too costly to do a complete workup on each of the patients. However, if you miss significant disease, sudden death may occur. "Missed myocardial infarction" is one of the most common reasons for a malpractice suit against an emergency physician and one of the most common reasons for losing a malpractice suit. The internist is also frequently sued for "missed myocardial infarction." Thus, the accuracy of the diagnosis is critical. The patient coming to the Emergency Department for chest pain but not having significant disease is a very large expense area for the insurance provider. The insurance provider therefore wishes to limit testing on these patients. The following is a discussion of some of the problems and pitfalls in dealing with acute cardiac ischemic syndromes.

The first areas that will be examined will be the areas of bystander/patient interactions, the pre-hospital transportation system, and the emergency department. Some of the problems and recent changes will be discussed. The greatest changes have been in the emergency department, less changes in the emergency medical service delivery, and very few changes in the bystander/patient interaction. They will be discussed in that order. Then the discussion will be on the accuracy of diagnosis in the Emergency Department.

EMERGENCY DEPARTMENT

The Emergency Department has many potential and real problems that can cause delays in the time to thrombolytic or other therapies. This delay time in the Emergency Department is due to many factors. The method of organization of the Emergency Department has been responsible for some of the delays. Patients with chest pain generally go through the registration system and are evaluated by a nurse who may order an ECG. They are then evaluated by a physician who is caring for other patients. In many studies the average time after entry into the system has been two hours. In the Seattle studies, the time before pre-hospital information was provided was 144 minutes. When information was obtained in the pre-hospital environment, the delay time was reduced to 72 minutes.[27] Seattle has shown that obtaining the ECG in the field and transmitting the ECG to the hospital allows the decision for thrombolytic therapy to be made by those physicians present in the Emergency Department and can reduce the time to thrombolytic therapy by 73 minutes in a comparative evaluation. In a large series from multiple hospitals, Kline et al[28] showed that in 1,423 patients the median time was 70 minutes from the time the patient came to the Emergency Department to the time the patient had thrombolytic therapy started. The National Heart Attack Alert Program (NHAAP)[9-10] of the National Heart Lung and Blood Institute of the NIH has published guidelines suggesting that the median door-to-needle time should be 30 minutes or less. When these

guidelines for door-to-needle time were published, there was a lot of discussion as to whether they were achievable, with some very strong descent. Gonzalez et al[29] showed that the median time could be reduced to 46 minutes in a multi center study. Several hospitals have achieved major reductions in this time. By taking a very aggressive approach to thrombolytic therapy, median times of 21 to 23 minutes have been achieved in a variety of community and public hospitals (personal communication Maine Medical Center, HCFA CCP project).

The Health Care Finance Administration (HCFA) has developed the Cooperative Cardiac Project (CCP) and has field tested it in four states. HCFA has now expanded this project nationwide. The project will come as a big shock to many physicians and hospitals. The charts of all patients who are in federally funded health care programs (Medicare, Medicaid, Champus, government employees, etc) who have had a discharge diagnosis of acute myocardial infarction are being extensively reviewed. Abstracting of all charts from the spring of 1994 to the spring of 1995 are at the present time being audited. Several markers are being examined for quality. The use of thrombolytic therapy in ideal patients, the door-to-needle time for thrombolytic therapy, the use of aspirin, the use of beta-blocking agents, the use of ACE inhibitors in patients with reduced ejection fractions, and smoking cessation counseling will be determined. Each hospital will receive a confidential letter stating what the rates for each of these interventions and time to treatment for thrombolytic therapy are. The hospital will be compared to state, national, regional, and best hospital norms. The hospitals will be asked to develop programs to improve their rates and times. Next year all patients who have had an acute myocardial infarction will be audited and comparative times and rates will be provided to the hospitals. Though HCFA and the PROs (peer review organizations) will not release this information, hospitals with good numbers will probably advertise the numbers, and hospitals not answering the questions about their times and rates from the news media and insurance providers will probably be assumed to have poor times and rates. This will probably cause a rapid nationwide reduction in the time to treatment with thrombolytic therapy and an increase in the usage of several therapies that can prolong life.

It is obvious that if thrombolytic therapy is going to have its best effect, the patient must be handled in an expeditious manner. The present organization and overload in many of the Emergency Departments of our hospitals have to be examined. The NHAAP has stated that there are four deadly "D's" that have to be evaluated.[9-10] The four "D's" are the four key times that can easily be measured that relate to the speed of administration of thrombolytic therapy. The times are the Door time (time of arrival at the Emergency Department), the Data time (time that the ECG is obtained along with a brief history and vital signs), the Decision time (time the physician decided to give thrombolytic therapy) and the Drug time (the time the thrombolytic therapy was actually given to the patient). Figure 4 shows some of the things that are happening in each of these time intervals. For the times to be minimized, hospitals must develop adequate quality improvement systems that analyze the delays and to try and develop methods of decreasing the delays. Known delays in an institution must be alleviated. Patients with acute cardiac ischemia should bypass many aspects of the registration system. They should immediately be taken to the appropriate patient care area and have immediate vital signs, limited history, and an electrocardiogram. The electrocardiogram should be done expeditiously. The electrocardiogram should be shown immediately to the physician in charge of

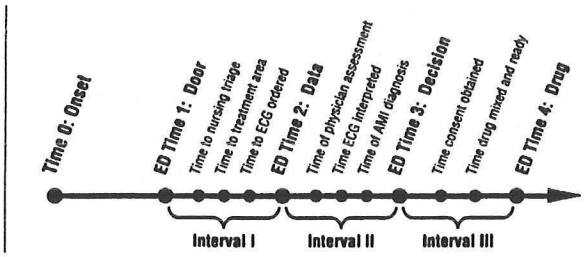


Fig 4. Emergency Department delay times[9-10]

the patient, and the physician should immediately make a decision on whether the patient is having an acute myocardial infarction. If the patient is having an acute myocardial infarction, the patient should be immediately evaluated to see if the patient is a candidate for thrombolytic therapy or for acute angioplasty. If the patient is a candidate for therapy, an immediate decision should be made by whoever is present to proceed with the therapy. Do not wait for a consultant to come and see the patient. If the physician is unsure about the ECG, then fax a copy to the cardiologist and make a decision over the telephone. Too much time is wasted repeating key information. The thrombolytic drug must be available in the Emergency Department and should be begun as fast as possible as an emergency procedure.

A system should be designed so that there is no delay in giving thrombolytic therapy once the decision has been made to give the drug. Private physicians should empower those present in the Emergency Department to give the agent if they are not present. Waiting for the admitting physician to come to the Emergency Department is responsible for major delays. Though no one system is perfect, each hospital should look at itself to determine how it can rapidly administer these agents.

Another consideration is transmission of a 12-lead ECG from the ambulance to the Emergency Department. Seattle has reported that when the physician at the hospital knows the history of chest pain and has an electrocardiogram showing the infarction, the time until the administration of thrombolytic therapy is greatly decreased. These might also give some time for notification of the admitting physician, so that the admitting physician in some cases could be available when the patient arrives in the Emergency Department. These changes should be considered.[9-10,27,30-31]

Though many reductions in time have occurred. There is one problem that is facing the Emergency Department. HMO's and managed care may require approval of all decision making and the decision to give thrombolytic therapy. Delays due to these entities must be resisted as they will reduce quality of care.

EMERGENCY MEDICAL SERVICES

The development of modern emergency medical services in the United States was sparked in the late 1960's and early 1970's by the occurrence of several different factors. The year 1966 was a pivotal year in the development of emergency medical services. The National Academy of Sciences, National Research Council issued two major policy statements. The first dealt with trauma, the neglected disease.[32] The second contained the recommendation that health professionals learn cardiopulmonary resuscitation.[33] The development of CPR followed Dr. Kouwenhoven's description of closed-chest cardiac massage in 1960.[34] Also in 1966, the first battery powered

defibrillator that was portable (74 lbs) became available. Over the next five years, many governmental agencies developed standards for training, ambulances, and every aspect of pre-hospital care. The American Heart Association developed training programs in resuscitation. The American College of Surgeons developed standards for trauma facilities. The American College of Orthopedic Surgeons developed training courses for a new breed of personnel: the Emergency Medical Technician - Ambulance. These factors pushed the development of emergency medical services from many angles. On the other side, the old system of multiple ambulance companies usually owned by funeral homes was starting to collapse for many different reasons. People began to expect that an ambulance would come to their aid within 10 minutes, not 30 minutes. There was an increased recognition by the public that there was a better system for treating patients.

Between 1969 and 1973, the pioneers in this field - Pantridge from Belfast, Cobb from Seattle, Nagel from Florida and Baltimore, Grace from New York, as well as many others - showed that patients could be resuscitated in the field and could later return to a useful, functional life. Successful resuscitations were demonstrated at large gatherings of people, such as at football games.[35-39] Pantridge and others in Ireland and Britain published data that physicians and nurses on board the ambulances could salvage a number of patients in the field.[40-47] In the United States, Grace also showed that patients could be resuscitated in the field.[48-49] A number of studies, particularly in the United States, demonstrated the effectiveness of telemetry of electrocardiograms, which brought about the establishment of paramedics and nurses providing pre-hospital care without a physician being present.[50-56] Finally, the success of these systems was demonstrated by Crampton, Nagel, Pantridge, Cobb, and others.[37,57-67]

In order for there to be rapid delivery of emergency medical services, there must be rapid access, effective dispatch, and rapid transport to an appropriate facility.

Access-- Time is a critical factor for the cardiac patient, both from the standpoint of cardiac arrest and from the potential administration of thrombolytic therapy. It is essential that access to emergency medical services be uniform and quick. A single, nationwide emergency number for emergency services - fire, police, and medical is essential; and the number should be the same - 911. Today 75-80% of the population are covered by 911. There are two types of 911 systems available. One version is the phone number 911 that connects the caller with an operator or dispatcher. A more sophisticated version is the enhanced 911 system that has automatic identification of the caller's telephone number and address. This latter variety has great advantages when dealing with an emergency situation in which people may not be able to communicate calmly the information required to obtain an emergency response. An enhanced 911 system should be a goal.[68-69]

Dispatch-- Centralized dispatch is required to provide fast and efficient emergency medical services. With a centralized dispatch, a quick and efficient response can be obtained by insuring that the closest available unit or units would respond. This is particularly important in areas where there are multiple agencies providing similar or the same service. The dispatcher should be trained to determine what services are needed. The need for centralized dispatch can also be illustrated by the requirements for a cardiac arrest victim. A cardiac arrest victim needs quick and efficient CPR as

well as defibrillation. Two individuals on an ambulance cannot quickly and efficiently handle a cardiac arrest victim; but with centralized dispatch of an integrated system, a fire engine or other First Responder could be sent to provide CPR and early defibrillation with an automated defibrillator, while the paramedic crew can provide the drug and other advanced therapy required in a rapid, efficient manner. For dispatch to be effective, dispatchers need to be trained. There is a need for EMD's, Emergency Medical Dispatchers. These dispatchers can determine the types of equipment and personnel required for the problem and can even provide first aid via the telephone. It has been shown that untrained telephone callers can be told how to do CPR until the system can respond. Thus, trained personnel can greatly improve the quality of dispatch.[70 -79] Efficient, centralized dispatch with trained dispatchers should be a national goal.

Pre-hospital 12-lead electrocardiograms for cardiac patients -- One recent advance in technology that may well change a number of factors is the use of 12-lead electrocardiograms in the pre-hospital arena. Paramedics can be taught to quickly perform ECGs both accurately and quickly. High quality 12-lead electrocardiograms with computerized interpretation can be transmitted by cellular phone or radio. This will be useful to the receiving hospital. If the receiving hospital has a 12-lead ECG that reveals an acute myocardial infarction along with appropriate history, the personnel in the hospital can be ready to give thrombolytic agents, beta blocking agents, nitroglycerin, or other agents as soon as the patient arrives - rather than being delayed while the hospital obtains that data after arrival. This will be of benefit. Seattle has shown that this is of marked benefit to the patient, greatly reducing the time to thrombolytic therapy and decreasing the morbidity and mortality.[12,80-81] We have obtained the equipment needed to perform 12-lead electrocardiograms in the Dallas paramedic program. To date we have done over 300 ECGs that have been reviewed. The quality of the ECGs is very good. Eighteen of the 300 ECGs have shown a definite acute myocardial infarction. Talking to the hospitals involved with several of these patients, the 12-lead ECG made a major difference in the care of the patient. In three cases, the pre-hospital ECG changed either the therapy that was given to the patient or greatly reduced the time to thrombolytic therapy.

The City of Dallas will have a cellular phone system in place for full use of the system in the next three to four weeks. This fall we will begin asking screening questions for thrombolytic therapy while en route to the hospital and relaying this information to the hospital before patient arrival. If the ECG shows a definite myocardial infarction and the patient is not a good candidate for thrombolytic therapy, the hospital may call the angioplasty team to come to the hospital before the patient even arrives, reducing the time to acute angioplasty.

PATIENT/BYSTANDER ACTIONS

No matter how great a system is organized, the patient must access the system. It is obvious that until the patient or bystanders decide to access the system, nothing can be accomplished. With cardiac patients, the patient may not realize that there is a problem. There is a major problem with access; the patient and the bystander must make up their minds that access is needed. Certain factors

have been shown to vary the time the patient delays before obtaining health care. These factors are summarized in Table 2.

Table 2. Factors That can Vary the Delay Time

Factors that may increase the delay time

- Older age
- Female gender
- African-American race
- Poor socioeconomic condition
- Lay consultation with spouse/friend
- Medical consultation
- Daytime onset of symptoms
- Being at home
- Stable angina
- Diabetes mellitus
- Self-treatment

Factors that may decrease the delay time

- Recognition of cardiac origin
- Severe pain
- Hemodynamically unstable
- Large infarct size
- Education?

Factors that do not change the delay time or are variable

- Day of the week
- Previous myocardial infarction
- Congestive heart failure
- Hypertension
- Known coronary artery disease

Though many studies have not found an effect of gender on the delay time, most of these studies have very few women.[13,15,20,82-87] Two studies have enough women to make a judgement of the effect of gender on the delay. Turi[23] found that the mean arrival time of women was 3.2 hours, while the arrival time for men was 3.0 hours. However, mean times can be very misleading. Alonzo,[22] in the largest study, revealed that the median time for arrival of women was 47 minutes longer than for men. This was due to a markedly prolonged self-evaluation time in women. One fascinating effect of gender on the delay was when men informed their wives of the symptoms - informing a wife greatly increased delay time.

The effect of race has not been well studied. Most of the studies have been in middle and upper income white males. One study has been quoted as showing that African-Americans have a decreased delay time; however, there were only four African-American patients out of 47 patients.[84] The largest number of African-American patients was in a study by Cooper,[16] in a poor and working class neighborhood in Chicago. These patients had a markedly prolonged delay time, with a median of six hours and mean times of 21-24 hours. However, Turi[23] found no difference between whites and non-whites. The breakdown of the non-whites was not given. Alonzo,[22] in the largest study, found that African-Americans had a longer delay, which was mainly due to younger African-American males trying to find a physician. The studies looking at race as a factor have looked at selected populations; there is insufficient information to draw proper conclusions. There is a need for research into the effects of different cultural groups in obtaining care.

Socioeconomic status has not been a factor in a number of studies.[13,18,21,83-84] However, these studies compared middle and upper income groups and did not contain truly disadvantaged groups. Cooper[16] found that the time was very long in a poor African-American population; but whether this was an African-American cultural effect or an effect of low socioeconomic status can not be determined. The one study that had proper balance between groups showed that low income greatly increased delay time as an independent predictor.[88-89]

Higher education does not have any effect on the delay time in a number of studies.[14,18,21,23,88,90] Lower education levels, less than high school graduation, caused a decrease in delay time in one small series.[84] Education about the signs or symptoms has not influenced delay time in some studies.[25,89] However, these studies have been short-term studies. The longest study in Gothenberg, Sweden did show that a mass education campaign could reduce delay times.[91] It should be noted that anti-smoking campaigns, cholesterol campaigns, and hypertension campaigns did not show any changes in behavior in the three to six months of the early studies. It was usually only after repeated campaigns over years that a change in behavior was seen. Short campaigns can change awareness of a problem, but it takes constant repetition over the years to modify behavior. For this reason, we have little information to understand how behavioral modification occurs in cardiac patients or any understanding of what would be required to modify behavior.

One study of personality traits showed that Type A personalities were slow in labeling their symptoms as cardiac in origin. Once Type A's did recognize that the symptoms were cardiac in nature, they rapidly obtained medical care. Type B personalities more quickly identified their symptoms as cardiac, but they were slow in obtaining medical care. Thus, overall, there was no difference in different personality types.[84]

The clinical status of the patient had an effect on delay time in some patients. Patients who were hemodynamically unstable had significantly decreased delay times.[23,85] Patients with large myocardial infarctions also had shorter delay times.[19] Overall severity of chest pain did not effect the delay.[19,85] However, for those with sudden onset of chest pain, increased severity did decrease the delay time.[13,22,88] Those patients who recognized that their symptoms were cardiac had a shorter delay, while those who thought their symptoms were gastrointestinal or pulmonary had a longer delay.[19]

The majority of studies has shown that a past medical history of cardiac disease either had little affect on delay times[13-14,18,21,23,85] or increased the delay times.[20-21,23] A history of previous myocardial infarction had no affect on delay times.[12-15,19,23,] History of coronary artery disease without infarction or congestive heart failure also did not have an effect on delay times.[15,21] Stable angina and angina with increasing severity prolonged the delay time.[15,21] Diabetes mellitus also increased the delay time.[20,23] Hypertension has had contradictory results, showing both an increase and a decrease in delay time.[13,23-24]

Most studies have looked at the patient's characteristics and ignored the role of third parties associated with the patient. Alonzo[22] has shown in a study of 1102 patients that 93.2% of the patients received lay consultation from a witness. Patients who make the decision by themselves[14,19] have a markedly shorter delay time than those who ask a family member about the symptoms.[13,22] As the most common lay consultants are family members, this causes the median times to increase from two hours to 12 hours in one study. The shortest delay occurs when an unrelated person assists in making the decision. The motivations for these delays by family members, friends, and co-workers are not clear. A common wish to deny the symptoms may play a role. Also, there may be an unwillingness of family, friends, or co-workers to confront the patient and push for early intervention. This may explain why family members and friends allow more delay than co-workers, while strangers allow very little delay.

Consulting a physician can also greatly increase the delay time.[15,18,21-22,24] The reasons for this delay are varied. Sometimes the physician orders therapy or denies that the patient could be having trouble. Sometimes the call is returned hours later or the office staff fails to have the patient go to the hospital.

Self-treatment by the patient significantly increased the delay time.[19,21-23] The patient frequently took over-the-counter medications or prescriptions and waited for the desired response. Delay time was particularly prolonged if the patient felt the symptoms were gastrointestinal and self-treated the symptoms. Americans tended to wait longer if the symptoms occurred during the day,[15,20,22] while British waited longer at night, and it made no difference to Canadians. The weekend has been shown to both increase and decrease the delay time.[14,18] Heavy exertion at the onset of pain has been shown to decrease the delay.[22] Place had some effect on delay times.[22-23,88] Those who had onset away from home and then went home had the longest delay. Most studies did not have many patients who had onset at work, though it appears that patients at the work site had shorter delays unless the patient went home.

Realizing that there are many complex reasons for these delays, then it makes sense to try and develop educational programs for the patients and most importantly the patients' families as the family often gives advice on whether to obtain medical assistance. The method of educating the family is not known. One major problem is that more patients may come to the Emergency Department with education and further overload the Emergency Department and increase health care costs. Dr. Goldman (personal communication) estimated five years ago that this would greatly increase cost; however that was based on three day hospitalizations. Now that patients usually are ruled out for acute cardiac ischemia with 23 hour observation status or less, the costs are less but

significant. The other major problem is in the area of diagnosis. Diagnosing acute cardiac ischemia is difficult at best. The remainder of this discussion will deal with problems in diagnosing acute cardiac ischemia when first seen in the Emergency Department or the physician's office.

HISTORY AND ELECTROCARDIOGRAM

History and the electrocardiogram are being considered together because they are integral portions of the decision making in acute cardiac ischemia. Obtaining an electrocardiogram in a patient with suspected acute cardiac ischemia should almost be considered a portion of the vital signs.

Case 1 - This is a 76 year old man who presented with a chief complaint of hiccoughs for 36 hours. He denied pain at the time. He had indigestion at the start of the hiccoughs. There was no other pertinent history or physical findings. He has a questionable history of hypertension.

Case 2 - This is a 32 year old woman who is seven months pregnant. The woman is complaining of exertional chest pain that is relieved by rest. The pain is occurring multiple times a day. She has no risk factors for CAD.

Case 3 - This is a 76 year old man who enters with indigestion. The indigestion has lasted for 45 minutes and is unrelieved by antacids that he has taken. He has elevated cholesterol. He is a smoker with 94 pack year history. His father died of a myocardial infarction at age 96.

When evaluating these patients, most of us would be worried about Case 3 because of the risk factors. These cases were picked to point out some of the common fallacies. Case 1 was thought to be nothing serious and the patient was sent home; fortunately an electrocardiogram was obtained and sent to the ECG lab for interpretation. The ECG in Case 1 revealed an acute inferior myocardial infarction; and the patient was called to return to the hospital, where he had post-infarction angina and a very rocky course requiring coronary artery bypass surgery. Case 2 would be considered by most individuals as a very unlikely patient. One very important piece of history was not mentioned. The patient had an acute anterior myocardial infarction two months before becoming pregnant and had an angioplasty of a 90% left anterior descending lesion. She is now being evaluated nine months after her angioplasty. She was treated with beta blocking agents and nitroglycerin and became pain free. Case 3 had a normal exercise test and a normal cardiac catheterization and was found to have esophagitis during a GI workup. These cases represent some of the problems in interpretation that will be discussed. The major factor that we look for in patients with suspected acute cardiac ischemia is the presence of chest pain or chest discomfort.

From the Framingham study and necropsy studies, clinically unrecognized, or silent myocardial infarctions, comprise between 30 and 40% of all myocardial infarctions (Table 3).[82,92-94] In the Framingham study, serial electrocardiograms revealed a 30% incidence of unrecognized transmural myocardial infarction. Half of these unrecognized myocardial infarctions had absolutely no symptoms when retrospectively questioned, while the other half had symptoms that would be very difficult for the patient to recognize so that the system could be accessed.[92-94] Similarly, it is

not possible for a cardiac arrest victim to recognize and access the system himself; so only the one-half of the victims who have a third party witness can receive rapid access. Though it might be possible to develop portable monitors to recognize cardiac arrest or ST segment changes and sound a warning to the patient or alert EMS, this approach is very impractical. Thus, one-third of myocardial infarction and one-half of cardiac arrest victims will not receive rapid entry into the health care system, even if all other factors could be controlled. Efforts must be expended to try to improve the system for the remaining patients.

Table 3. Ten-Year Incidence (Rate per 1000) of Myocardial Infarctions Among 2272 Men and 2845 Women at Risk, According to Age and Sex*

	Men		Women	
Age	Unrecognized Infarcts	All Infarcts	Unrecognized Infarcts	All Infarcts
30-34	2.6 (28.6)	12.9	0.0 (0.0)	2.2
35-44	6.5 (17.9)	38.2	2.6 (41.2)	5.2
45-54	16.6 (25.4)	71.2	2.9 (30.5)	13.0
55-64	28.2 (29.1)	107.9	17.9 (34.7)	47.1
65-74	53.8 (41.9)	141.0	21.3 (35.7)	55.7
75-84	60.2 (33.3)	12.8	34.0 (45.5)	128.3
TOTAL	(27.7)		(34.7)	

*Figures in Parentheses Indicate Per Cent of all infarctions that are unrecognized
Kannel. N Engl J Med 1984;311:1144.

Hence, the sensitivity of our most important determinant for starting a workup of acute cardiac ischemia, chest pain, is only in the 65%-73% range. It must be recognized that a significant number of patients are missed and will continue to be missed with any present technology as they do not have a symptom that will even prompt them to obtain help.

Cardiac pain or discomfort is visceral in nature. Visceral pain or discomfort have several problems that are well known. The symptoms are very difficult for the patient to interpret, causing delays and misjudgments and poor descriptions. Further visceral pain or discomfort is commonly seen in patients with all types of gastrointestinal ailments. The ability of the patient to differentiate between these different types of visceral pain is poor. Patients with known disease in both systems often have difficulty telling which type of pain they are having. Patients with angina pectoris frequently have hiatal hernia, another very common disorder. Many patient have difficulty telling the difference between the symptoms of reflux and the symptoms of angina pectoris. This points out a major problem with visceral pain.

The significance of various aspects of history and ECGs is best described by the group where Harry Selker is the senior author.[26] Last year Dr. Selker presented materials to a committee that I chair looking at various aspects of history in patients with acute cardiac ischemia. Dr. Selker kindly gave me the charts from this presentation and has allowed me to use them. The data are shown in a number of Tables listed under Tables 3, 4, and 5.

In this study Dr. Selker and co-investigators defined acute cardiac ischemia as either acute myocardial infarction (AMI) or angina, either new onset or unstable angina. The data was compiled by the Center for Cardiovascular Health Services Research (CCHSR). Data was obtained from two major urban teaching centers, two teaching-affiliate hospitals in smaller cities, and two rural non-teaching hospitals. The inclusion criteria were men 30 years of age or older and women 40 years of age or older. All patients had presented to the hospital Emergency Department with chest pain, arm pain, stomach pain, shortness of breath, or dizziness. The diagnosis of acute cardiac ischemia or not was the discharge diagnosis after workup. The study was comprised of 5,768 patients of whom 56% were men.

Chest pain was the primary symptom in only 45% of patients. Chest pain was a secondary symptom in 34% of patients. Hence, the sensitivity of chest pain appears to be 79% in this study. However, remember one-third of patients with an acute myocardial infarction never come to the hospital with an acute event; hence, the true sensitivity is 79% times 73%(the percentage not having silent myocardial infarction) or 58% in men, and 79% times 66% or 52% in women. This might be an overestimate of the sensitivity, as there is some bias of the physician who is working up these patients, and they may have excluded some as atypical chest pain; as the figures are calculated from final diagnoses. Arm pain was seen in 38% of patients with acute cardiac ischemia. Stomach pain and the primary symptom of shortness of breath or dizziness were not as important as chest or arm pain.

When you start examining other portions of the history other than the quality of the present complaint, one must be very careful not to fall into a number of traps. There is not a substantive difference between men or women in their presenting complaints. Biases for or against the presenting complaints in women are not justified in this data. It should be understood, however, there may have been bias in making the original diagnosis that the data can not examine. Past history was not a strong predictor of who had disease. When you look at prior myocardial infarction or nitroglycerin usage in patients presenting with chest pain, the highest incidence of acute cardiac ischemia was in those patients with both a prior myocardial infarction and nitroglycerin usage (63%); while in patients with chest pain but neither prior infarction or nitroglycerin usage the incidence of acute cardiac ischemia with chest pain was 34%. When you look at the electrocardiogram, ST segment changes and peaking or inversion of the T waves did correlate with acute events.[26] The presence of Q waves picked out patients more likely to have acute cardiac ischemia when combined with chest pain. Patients with chest pain and Q waves had a 69% incidence, while those with chest pain without Q waves had a 36% incidence. Patients with chest pain and LVH and RBBB did not have a higher incidence than the normal patients; patients with LBBB had a somewhat higher incidence as compared to normal. When you try combining many of these factors, you can identify some groups with higher versus lower risk; but the risk is

What symptoms should alert individuals as possible acute cardiac ischemia (ACI)?

Primary Symptom	% with ACI (n=5,768)
Chest Pain Sx1	45 (3,288)
Chest Pain Sx2	34 (605)
Arm Pain	38 (98)
Stomach Pain	14 (233)
SOB Sx1	17 (658)
Dizzy Sx1	9 (613)
Other	13 (273)
All	34 (5,768)

Within the high risk group of patients with a history of coronary disease are there differences between women and men?

Patients with Coronary Disease by History or ECG

Primary Symptom	% with ACI (n=3,055)		
	All	Women	Men
Chest Pain Sx1	59 (1,838)	53 (802)	64 (1,036)
Chest Pain Sx2	42 (354)	40 (151)	43 (206)
Arm Pain	54 (50)	58 (24)	50 (26)
Stomach Pain	26 (97)	23 (39)	28 (58)
SOB Sx1	23 (381)	23 (176)	22 (205)
Dizzy Sx1	17 (215)	13 (91)	20 (124)
Other	18 (120)	17 (65)	18 (55)
All	47 (3,055)	43 (1,348)	50 (1,707)

Does history of coronary disease identify a group at high risk for acute cardiac ischemia (ACI)?

Primary Symptom	% with ACI (n=5,768)				
	All	No MI or NTG Hx	Hx NTG	Hx MI	MI and NTG Hx
Chest Pain Sx1	45 (3,288)	34 (1,769)	50 (446)	58 (350)	63 (723)
Chest Pain Sx2	34 (605)	25 (310)	35 (82)	44 (90)	34 (605)
Arm Pain	38 (98)	31 (62)	67 (3)	36 (14)	58 (19)
Stomach Pain	14 (233)	10 (155)	6 (16)	20 (30)	34 (32)
SOB Sx1	17 (658)	13 (381)	20 (50)	35 (146)	25 (81)
Dizzy Sx1	9 (613)	4 (436)	14 (44)	17 (66)	25 (67)
Other	13 (273)	11 (181)	13 (24)	23 (35)	15 (33)
All	34 (5,768)	24 (3,294)	41 (665)	42 (731)	53 (1,078)

Does history of coronary disease identify a group at high risk for acute cardiac ischemia (ACI)?

Primary Symptom	% with ACI (n=5,768)		
	All	No MI or NTG Hx	MI or NTG Hx
Chest Pain Sx1	45 (3,288)	34 (1,769)	58 (1,519)
Chest Pain Sx2	34 (605)	25 (310)	42 (295)
Arm Pain	38 (98)	31 (62)	50 (36)
Stomach Pain	14 (233)	10 (155)	23 (78)
SOB Sx1	17 (658)	13 (381)	24 (277)
Dizzy Sx1	9 (613)	4 (436)	19 (177)
Other	13 (273)	11 (181)	17 (92)
All	34 (5,768)	24 (3,294)	47 (2,474)

Does an abnormal ECG identify a group at high risk for acute cardiac ischemia (ACI)?

Primary Symptom	% with ACI (n=5,768)				
	Normal	Q-waves	LVH	LBBB	RBBB
Chest Pain Sx1	36 (1,974)	69 (878)	36 (251)	54 (46)	33 (51)
Chest Pain Sx2	29 (326)	47 (172)	22 (50)	36 (25)	35 (17)
Arm Pain	25 (51)	67 (33)	13 (8)	20 (2)	0 (2)
Stomach Pain	7 (142)	42 (48)	4 (23)	20 (5)	11 (9)
SOB Sx1	11 (264)	26 (221)	13 (90)	12 (42)	20 (20)
Dizzy Sx1	6 (408)	21 (107)	4 (52)	0 (14)	5 (19)
Other	10 (166)	25 (55)	10 (31)	20 (5)	11 (9)
All	27 (3,331)	54 (1,514)	24 (505)	30 (139)	24 (127)

Does an abnormal ECG identify a group at high risk for acute cardiac ischemia (ACI)?

Primary Symptom	% with ACI (n=5,768)		
	All	No Q-waves	Q-waves
Chest Pain Sx1	45 (3,288)	36 (2410)	69 (878)
Chest Pain Sx2	34 (605)	29 (433)	47 (172)
Arm Pain	38 (98)	23 (65)	67 (33)
Stomach Pain	14 (233)	7 (185)	42 (48)
SOB Sx1	17 (658)	13 (437)	26 (221)
Dizzy Sx1	9 (613)	6 (506)	21 (107)
Other	13 (273)	10 (218)	25 (55)
All	34 (5,768)	27 (4254)	54 (1,514)

Does history of heart attack *or* nitroglycerine use *or* an ECG with a Q-wave identify a group at high risk for acute cardiac ischemia (ACI)?

Coronary Disease by History or ECG

Primary Symptom	% with ACI (n=5,768)		
	All	Non-CHD risk	CHD risk
Chest Pain Sx1	45 (3,288)	27 (1,450)	59 (1,838)
Chest Pain Sx2	34 (605)	22 (251)	42 (354)
Arm Pain	38 (98)	21 (48)	54 (50)
Stomach Pain	14 (233)	6 (136)	26 (97)
SOB Sx1	17 (658)	10 (277)	23 (381)
Dizzy Sx1	9 (613)	4 (398)	17 (215)
Other	13 (273)	10 (153)	18 (120)
All	34 (5,768)	19 (2,713)	47 (3,055)

Does diabetes add to history or ECG in identifying a high risk group for acute cardiac ischemia (ACI)?

Patients without Coronary Disease by History or ECG

Primary Symptom	% with ACI (n=2,693)		
	All	No diabetes	Diabetes
Chest Pain Sx1	27 (1,445)	26 (1,309)	44 (136)
Chest Pain Sx2	21 (247)	21 (217)	27 (30)
Arm Pain	21 (48)	21 (42)	17 (6)
Stomach Pain	6 (135)	3 (116)	21 (19)
SOB Sx1	10 (273)	10 (236)	14 (37)
Dizzy Sx1	4 (395)	4 (343)	2 (52)
Other	10 (150)	11 (128)	5 (22)
All	19 (2,693)	19 (2,391)	26 (302)

Table 3: CCHSR data for determining patients at high risk for acute cardiac ischemia. Selker, personal communication.

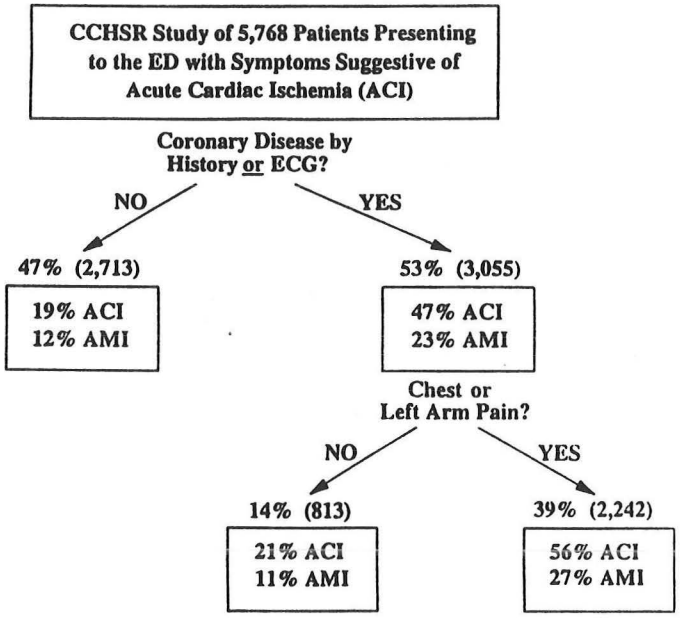
Does age 70 or more years add to history or ECG in identifying a high risk group for acute cardiac ischemia (ACI)?

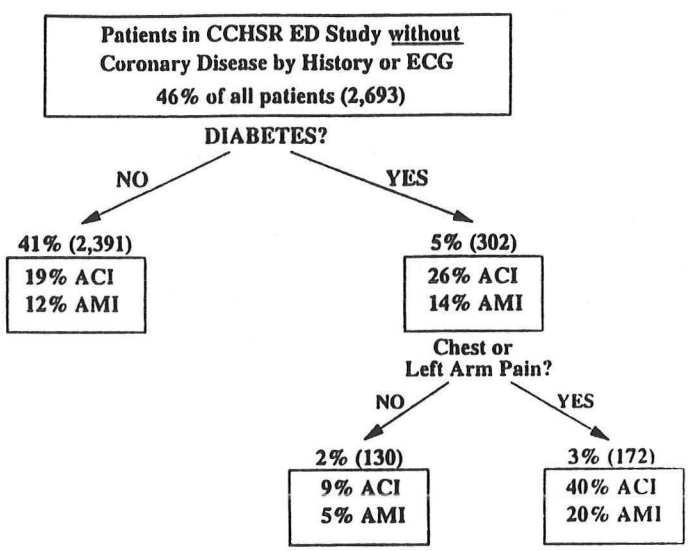
Patients without Coronary Disease by History or ECG

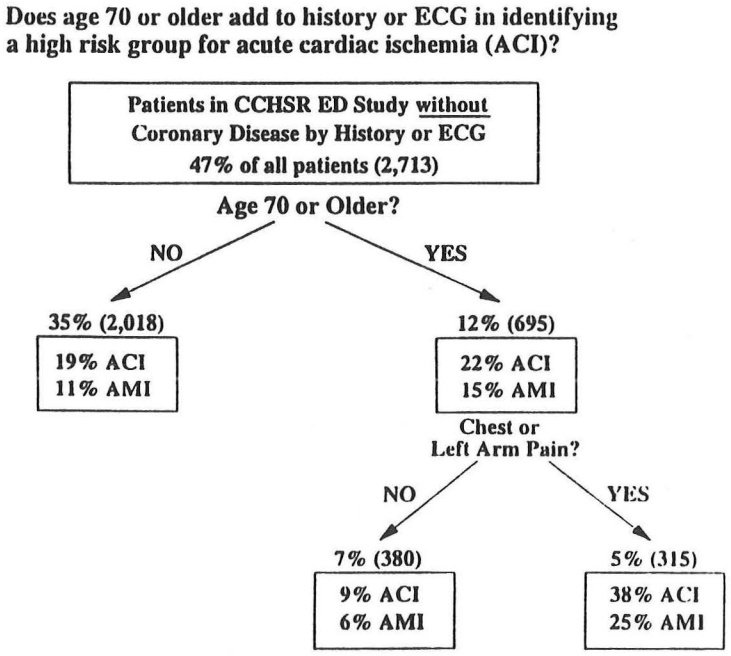
Primary Symptom	% with ACI (n=2,713)		
	All	Age < 70	Age ≥ 70
Chest Pain Sx1	27 (1,450)	25 (1,204)	41 (246)
Chest Pain Sx2	21 (251)	19 (195)	30 (56)
Arm Pain	21 (48)	20 (35)	23 (13)
Stomach Pain	6 (136)	5 (95)	7 (41)
SOB Sx1	10 (277)	7 (138)	14 (139)
Dizzy Sx1	4 (398)	3 (247)	6 (151)
Other	10 (153)	12 (104)	6 (49)
All	19 (2,713)	19 (2,018)	22 (695)

Does history of heart attack *or* nitroglycerine use *or* an ECG with a Q-wave *or* diabetes identify a group at high risk for acute cardiac ischemia (ACI)?

Primary Symptom	% with ACI (n=5,768)		
	All	Non-CHD risk	High CHD risk
Chest Pain Sx1	45 (3,288)	26 (1,314)	58 (1,974)
Chest Pain Sx2	34 (605)	21 (221)	41 (384)
Arm Pain	38 (98)	21 (42)	50 (56)
Stomach Pain	14 (233)	3 (117)	24 (116)
SOB Sx1	17 (658)	10 (240)	22 (418)
Dizzy Sx1	9 (613)	4 (346)	14 (267)
Other	13 (273)	11 (131)	15 (142)
All	34 (5,768)	19 (2,411)	45 (3,357)







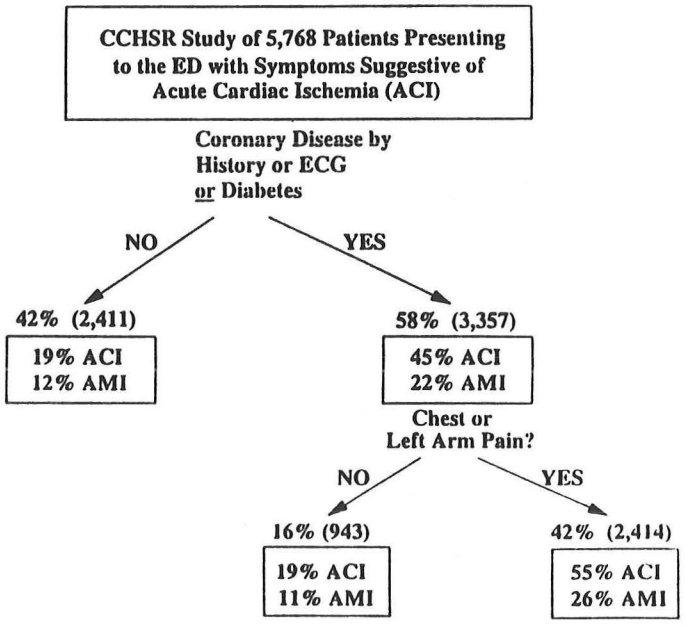


Table 4: CCHSR data for determining patients at high risk for acute cardiac ischemia. Selker, personal communication.

Does history of heart attack *or* nitroglycerine use *or* an ECG with a Q-wave *or* diabetes *or* age 70 or more years identify a group at high risk for acute cardiac ischemia (ACI)?

Primary Symptom	% with ACI (n=5,768)		
	All	Non-CHD risk	High CHD risk
Chest Pain Sx1	45 (3,288)	29 (1,301)	56 (1,987)
Chest Pain Sx2	34 (605)	24 (204)	39 (401)
Arm Pain	38 (98)	26 (35)	44 (63)
Stomach Pain	14 (233)	4 (89)	20 (144)
SOB Sx1	17 (658)	8 (137)	20 (521)
Dizzy Sx1	9 (613)	3 (234)	12 (379)
Other	13 (273)	13 (106)	13 (167)
All	34 (5,768)	22 (2,106)	41 (3,662)

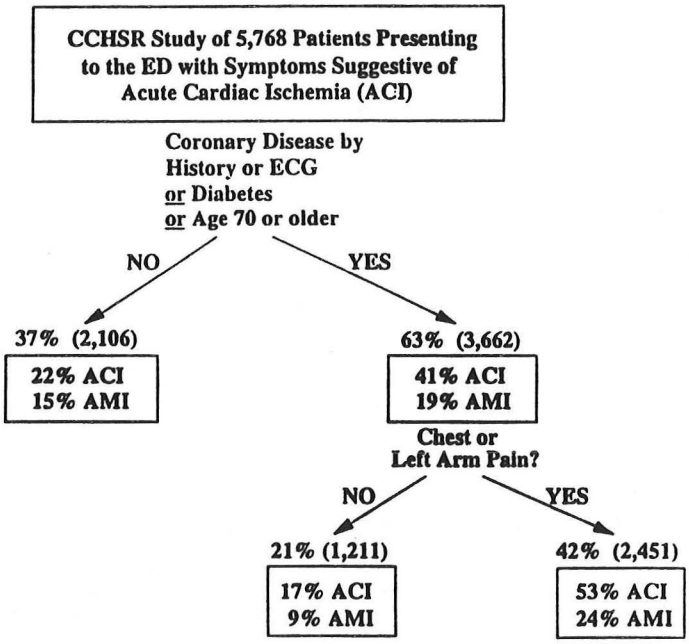


Table 5: CCHSR data for determining patients at high risk for acute cardiac ischemia. Selker, personal communication.

substantial in both groups. If you look for a history of infarction or nitroglycerine use or Q waves or any combination of these three, 59% of the patients with chest pain had acute cardiac ischemia while patients with none of these had a 27% incidence. Diabetes also was a discriminating factor. Diabetics with chest pain had a 44% incidence, while non-diabetics had a 26% incidence. Combining diabetes with all of the other best factors does not help. Age, though it correlates with a higher incidence, is not a good discriminator.

Table 6 shows the odds ratios of a number of different factors in men and women for predicting who has acute cardiac ischemia. As can be see in this table, chest pain is the best discriminator of an event. ST segment elevation or flattening is the second best discriminator followed closely by T wave peaking or inversion. Risk factors and prior history were very poor discriminators. The reason for this is probably that patients who have had a prior event or are at high risk come in more frequently as they have just as difficult a time determining the nature of their symptoms as those with no history or risk factors. Patients with prior myocardial infarctions delay as long the second time as the first and they come in as often for symptoms that are non-cardiac in nature as patients with no prior history. The sensations that are visceral are difficult for the patient to interpret. People who have had prior events are more frightened of any visceral symptom.

Table 6 Relative risks for acute ischemia of coronary risk factor reports and other presenting features

	Relative risk (95% CI)	
	Men (n=1008)	Women (n=735)
Risk factor reports		
Hypercholesterolemia	1.3(0.6-2.5)	1.1(0.4-2.8)
Diabetes	2.4(1.2-4.8)	2.0(0.9-4.2)
Cigarette smoking	1.5(1.0-2.4)	1.0(0.6-1.9)
Hypertension	1.0(0.7-1.7)	1.6(0.9-2.8)
Family hx MI	2.1(1.4-3.3)	1.2(0.7-2.2)
Family hx MI<age 50	1.5(0.7-2.8)	0.9(0.4-2.0)
Clinical variables		
Chest pain or pressure	12.1(5.3-27.6)	25.0(5.8-109.6)
ST Elevation or flat	8.7(5.0-14.8)	3.9(2.2-6.9)
T peaked or inversion	5.3(3.1-8.8)	4.0(2.2-7.4)

Jayes. J Clin Epidemiol 1992;45:621[26]

Though there are great volumes written about the description of chest pain or discomfort in patients with myocardial infarction or unstable angina pectoris, there is little data that has been examined prospectively. As there is little data, then let us look at various clinical guidelines that have been published. The first to be discussed is that in the Emergency Department paper developed

by the National Heart Attack Alert Program.[9-10] The NHAAP described the chief complaint as follows:

- Chest pain. Patients over 30 years of age with chest pain or severe epigastric pain, nontraumatic in origin, having components typical of myocardial ischemia or infarction:
  - Central/substernal compression or crushing chest pain
  - Pressure, tightness, heaviness, cramping, burning, aching sensation
  - Unexplained indigestion/belching
  - Radiating pain in neck, jaw, shoulders back, or one or both arms
- Associated dyspnea
- Associated nausea/vomiting
- Associated diaphoresis

The American College of Emergency Physicians in its recent position paper has made some simple recommendations.[95] These are divided into several categories as follows:

- Pain ongoing **and** severe **and** crushing **and** substernal **or** same as previous pain diagnosed as MI - **ECG, treat as MI, Admit**
- Severe **or** pressure **or** substernal **or** exertional **or** radiating to jaw, neck, shoulder, or arm - **ECG,** consider treating as MI, consider Admit
- Tearing, severe, and radiating to back - **ECG, CXR,** consider aortic imaging, consider Admit
- Similar to that of previous pulmonary embolus - **ECG, ABG, Pulmonary imaging,** consider Admit
- Indigestion or burning epigastric - consider ECG
- Pleuritic - consider CXR, consider ECG

Additional recommendations are found in the guidelines.[95]

The Agency for Health Care Policy and Research also made some recommendations in their guidelines for unstable angina.[96] They defined angina as findings typical of angina or ischemic heart disease and tried to define what was not angina. Criteria for **NOT** angina are:

- Pleuritic pain; i.e., sharp or knife-like pain brought on by respiratory movement or cough
- Primary or sole location of discomfort in the middle or lower abdominal region
- Pain localized with one finger
- Pain reproduced by movement or palpation of chest wall or arms
- Constant pain lasting for days
- Very brief episodes of pain lasting a few seconds or less
- Pain radiating to the lower extremities

These criteria do not rule out very many patients. It should be pointed out that in a multicenter chest pain study that 22% of patients presenting with sharp or stabbing pain and 13% with some elements of pleuritic pain ended up having acute cardiac ischemia.[97] Also 7% of patients whose pain was fully reproduced by palpation were found to have acute cardiac ischemia.[97] Pain elicited by pressing on the second left costochrondal junction may be referred cardiac pain.

The prudent physician must approach chest pain or discomfort with care. No criteria can fully predict who may or may not have acute cardiac ischemia. The physician must maintain an open mind and not jump to conclusions that the pain is not cardiac in nature.

The electrocardiogram is an essential portion of the evaluation of a patient with possible acute cardiac ischemia. When transmural myocardial infarction is examined, the electrocardiogram has a sensitivity of 61% and a specificity of 95% with a positive predictive value for infarction of 73% and a negative predictive value of 92%.[98] Though that sounds relatively good, there are a number of problems. First is the interpretation of the electrocardiogram in the Emergency Department. When the interpretation is reviewed by the cardiologist, more patients are described as having acute cardiac ischemia; in fact when patients are later found to have acute cardiac ischemia but are sent home, 25% of these "missed ischemia" were due to misinterpretation of the ECG in the Emergency Department.[98-99] The sensitivity can be increased if the following are considered positive for acute myocardial infarction:

- nonspecific ST or T wave changes not diagnostic of ischemia
- ischemia, strain, or infarction - known to be old
- ischemia, strain, or infarction - not known to be old
- probable infarction

These criteria increase the sensitivity to 99% but drop the specificity to 23%; the positive predictive value is 21% and the negative predictive value is 99%. Thus, if none of these parameter are present, the likelihood that acute cardiac ischemia is present is very low. However many patients have nonspecific ST and T wave changes; these changes are frequently just flattening of the T wave or the ST segment which can be seen with almost any illness. The ability of the electrocardiogram to detect new ischemia in patients with prior myocardial infarctions is reduced. The presence of LVH greatly reduces the sensitivity of the ECG. Obviously patients with prior myocardial infarctions or LVH are at increased risk of events. LBBB reduces the sensitivity to an extremely low level. Early repolarization also greatly reduces the sensitivity and specificity of the ECG. The criteria for diagnosis of non Q wave infarction or unstable angina pectoris is more difficult. Many of these patients will have no or minimal changes. Minor T wave changes or ST segment changes that are transient are one of the more frequent findings.

ADJUNCTS TO THE DIAGNOSIS OF ACUTE CARDIAC ISCHEMIA

CARDIAC ENZYMES

Enzyme determinations can help determine the patient who is having an acute myocardial infarction. The MB isoform of creatine kinase is an accurate method of determining acute myocardial infarction. The only problem with CK-MB is the time to obtain the determination and the accuracy of the determination early in the course of the acute event. The sensitivity of CK in the Emergency Department has been reported to be from 38% to 54%. Use of the isoform CK-MB in combination with CK does not help. When a value of CK-MB to CK of >5% is seen in the Emergency Department, the sensitivity ranges from 34% to 57%. Use of subfractions of CK-MB may improve the sensitivity as well as using much lower normal limits; however this has not been adequately studied. When CK-MB is used serially, it becomes very sensitive. From onset of pain, the time delay is frequently four to six hours before the CK and CK-MB are abnormal. At four hours after Emergency Department arrival (2-4 hours after onset of pain), the sensitivity is 56% and by 10-11 hours the sensitivity has been reported to approach 100% with serial determinations. One study has suggested that multiple serial determinations in the first three hours may give a sensitivity and

specificity of >90%. At the present time, CK-MB is only useful if it is positive with a single determination. With serial determinations over 10-11 hours, it becomes very sensitive for acute myocardial infarction.[100-103] Thus serial comparisons over time is the only effective way of using CK-MB and CK determinations. A single CK or CK-MB determination in a patient who is sent home is a high legal risk if the patient has an event after discharge.

Myoglobin is detectible in two-thirds of the patients at three hours and in most all patients by six hours. However it lacks specificity. The high sensitivity is obtained by using low positivity criteria which diminishes its specificity. By 8-12 hours, myoglobin has a sensitivity of >95%.[104-109] Troponin I and troponin T also can also be used to determine the presence of myocardial infarction. Troponin T has a sensitivity of 33% at 0-2 hours, 50% at 2-4 hours, and 75% at 4-8 hours. Sensitivity is over 90% by serial determinations over 24 hours. specificity is reported as 95%; unstable angina has elevated troponin T in 21% of patients. Five percent of nonischemic chest pain patients have elevated troponin T.[107,110-118] It has been suggested that combinations of two markers may increase sensitivity early. This is an interesting hypothesis but lacks sufficient clinical information.

ECHOCARDIOGRAPHY

Echocardiography is a technique that can be performed in the Emergency Department on an urgent basis. Echocardiography has been shown to be an effective method of diagnosing coronary artery disease in patients. The major finding that suggests the presence of CAD is wall motion abnormalities where a hypokinetic or akinetic segment is seen. When echocardiography is combined with stress it is a useful tool. Identification of abnormal wall motion segment in the Emergency Department has been studied. In the best of hands, 90% of patients could be imaged so that the echocardiogram can be interpreted.. This 90% successful imaging rate was achieved by having an experienced technician spend one hour on each patient. With these criteria, imaging had a sensitivity of 88% and a specificity of 78%, if the imaging was done prior to relief of chest pain. Though the technique has some utility, several problems exist. These results were obtained with an experienced technician, an expert interpreter, in patients with normal ECGs previously, and who had ongoing chest pain. As abnormal wall motion or lack of wall thickening are the objects of doing the echocardiogram, old wall motion abnormalities from prior infarction cannot be differentiated. Patients with dilated or hypertrophic cardiomyopathy, hypertrophic ventricles, and LBBB may have wall motion abnormalities that can be confused with CAD. Thus, the role of echocardiography is limited in the Emergency Department.[119-127]

NUCLEAR SCANNING AND MRI

Thallium imaging for the detection of acute myocardial infarction has been studied only in a retrospective manner in a handful of patients. Thallium imaging is not very promising in the Emergency Department, due to the lack of predictability of when the Thallium would be needed (and it must be ordered in advance). Sestamibi perfusion imaging is easier to do in the Emergency Department patient, as the Technetium is available from generators within the institution. One study of 45 patients in the hospital with unstable angina pectoris showed that a single study could pick up

abnormalities in a large percentage of patients. The sensitivity was 96% with a specificity of 79% in patients with chest pain. Problems with sestamibi imaging are that you must wait one hour after a dose to allow clearance from the liver. Wall motion abnormalities and lack of thickening can be identified with scans but have the same problems as echocardiography in evaluating wall motion and thickening; they can evaluate more patients than echocardiography as echocardiography has a number of studies that cannot be evaluated. Imaging can also look at perfusion; however a resting scan cannot differentiate old infarction from new infarction. If the scan is negative, then the likelihood of significant CAD is minimal. One suggestion is that you do a resting sestamibi scan in the Emergency Department and if negative send the patient home to return the next day for a stress or adenosine scan to rule out disease. This strategy may be of benefit. PET scans and MRIs have been also suggested as having possibilities. The problems with these techniques are availability. MRI can also be used to look at wall motion and wall thickening. In the future MRI and scanning may have additional benefits. There are experimental methods of imaging injured muscles with a positive image rather than a hole. If positive imaging of an infarcting area can be accomplished, this might well be a technique that can be used acutely.[128-139]

ACI Predictive Instrument

This technique uses a hand held calculator into which a number of variables are placed. The variables include:

- Chest pain or left arm pain/discomfort
- Chest or left arm discomfort the most important presenting symptom
- History of a previous myocardial infarction
- History of use of nitroglycerine for chest pain
- ECG ST segment flattening ("straightening") in two or more leads
- ECG ST elevation or depression of =or> 1 mm in two or more leads
- ECG T wave elevation ("Hyperacute") or =or> 1 mm inversion in two or more leads

The technique has been very helpful in reducing the number of hospital admissions of patients who turned out not to have acute cardiac ischemia. Hospital admissions that turned out to be negative were reduced by 30%. This technique looks very impressive; however, the device is not readily available.[140-146]

OTHER TECHNOLOGIES

Several computer aided methods have been used to aid in the diagnosis. The best known of these is the one developed by Goldman. Though these techniques have some promise, they have not yet been shown to affect outcome. The Goldman chest pain protocol when compared to physicians had exactly the same sensitivity of 88% as did the physicians. The specificity was better with the protocol than with physician 75% versus 71%. The overall accuracy was increased from 73% to 76% by use of the protocol. Physicians in the institution have not changed behavior based on the protocol.[147-164] Surface mapping could improve the sensitivity; right sided electrodes may add some benefit in patients with inferior or posterior myocardial infarction. There is no study of this technique in the emergency setting to test its validity. Continuous monitoring of ST segments has also been suggested; however,only no study exists to point out their true benefit in emergency setting.

GUIDELINES FOR DETERMINING ADMISSION FOR UNSTABLE ANGINA

The AHCPR has developed guidelines for unstable angina.[96] The guidelines include criteria for assessing the likelihood of CAD and for the risk of CAD. Criteria for likelihood of CAD with symptoms of unstable angina are as follows:

High likelihood (any one of the following)
- Known history of CAD
- Definite angina: males > 60 or females > 70
- Hemodynamic changes or ECG changes with pain
- Variant angina
- ST segment change of 1 mm or greater (increase or decrease)
- Marked symmetrical T wave inversion in multiple precordial leads

Intermediate likelihood (no high likelihood finding and any one of the following)
- Definite angina: males < 60 or females <70
- Probable angina: males > 60 or females > 70
- Probably not angina in diabetics or in non-diabetics with two or more risk factors (Diabetes, smoking, hypertension, elevated cholesterol)
- Extracardiac vascular disease
- ST segment depression 0.05 to 1 mm
- T wave inversion of 1 mm or greater in leads with dominant R waves

Low likelihood (no high or intermediate likelihood finding and any one of the following)
- Chest pain, probably not angina
- One risk factor, but not diabetes
- T wave flat or inverted < 1 mm in leads with dominant R waves
- Normal ECG

Then determine the degree of risk using the following criteria:

High risk (any one of the following)
- Prolonged ongoing rest pain (> 20 minutes)
- Pulmonary edema
- Angina with new or worsening mitral regurgitation murmurs
- Rest angina with dynamic ST changes of 1 mm or greater
- Angina with S3 or rales
- Angina with hypotension

Intermediate risk (no high risk and any one of the following)
- Rest angina now resolved but not low likelihood of CAD
- Rest angina (> 20 minutes or relieved with rest or nitroglycerin)
- Angina with dynamic T wave changes

- Nocturnal angina
- New onset Class III or IV angina in past 2 weeks but not low likelihood of CAD
- Q waves or ST depression of 1 mm or more in multiple leads
- Age > 65 years

Low risk (no high or intermediate risk and any one of the following)
- Increased angina frequency, severity or duration
- Angina provoked at a lower threshold
- New onset angina within 2 weeks to 2 months
- Normal or unchanged ECG

If either the likelihood or risk is high, admit the patient to the CCU and consider reperfusion. If either the likelihood or risk is intermediate, admit the patient to a ward service and proceed with rule out infarction and workup. If both the risk and likelihood is low, then work up patient as an outpatient.[96]

APPROACH TO THE PATIENT

The approach to the patient should be stepwise in nature. The approach should be rapid and methodical. It is important to consider the timing of each portion of the decision process. Accuracy and cost effectiveness should also be considered.

Step 1 - Obtain a limited history and an electrocardiogram

1. The history should be limited to the present illness - NOT past history or risk factors (the one exception is if the patient has had a prior MI is the pain the same)
2. The electrocardiogram should be interpreted to see if there is localized ST segment elevation is present, ST depression is present, the T waves are peaked, or inverted

If the history is strongly suggestive or the ECG has changes mentioned (exception that the changes on ECG are old and are absolutely unchanged) **Admit the patient and consider thrombolytic therapy or angioplasty**

This step will remove from further consideration 65% of the acute MIs and 35-50% of the unstable angina and non Q wave Mis

Step 2 - Recheck history and electrocardiogram

If the story is not good for cardiac ischemia and the ECG is normal, see if you can diagnose a non-cardiac lesion.

If the story is not very good for cardiac ischemia but the ECG is abnormal and unchanged, consider observation for a period of time.

Step 3 - Patients not excluded in step 1 or 2, should have serial cardiac enzymes (8 or 23 hours??)

If the enzymes are positive, admit the patients

Step 4 - Evaluate whether the patient is at risk for cardiac ischemia using the AHCPR guidelines

If the patient is high likelihood or high risk, admit to CCU

If the patient is intermediate likelihood or risk, admit observation for at least 23 hours

If the patient is low likelihood and risk, then schedule a diagnostic study as an outpatient.

Obviously, these are guidelines and will not accurately predict each case. The division between a good story and not a good story is murky at best. One must be prudent in the use of guidelines. Even with the best physician and meticulous attention, patients will be missed. Great care and prudence are the best recommendation.

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