MEDICAL GRAND ROUNDS

IMPROVEMENTS IN THE MANAGEMENT OF CARDIAC ARREST

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When in the stream by accident, is found
A pallid body of the recent drown'd.
Tho ev'ry sign of life is wholly fled,
And all are ready to pronounce it dead,
With tender care the clay-cold body lay
In flannel warm, and to some house convey:
The nearest cot, whose doors still open lie
When mis'ry calls, will ev'ry want supply.

...But, ah! A fatal error oft has been,
When life, though latent, was not quickly seen.
Then thinking that the conflict all was o'er;
That life was fled, and could return no more,
Who much have wish'd, and yet despair'd to save,
Too rashly doom'd the body to the grave.
More patient thou, with ardour perservere
Four hours at least: the gen'rous heart will fear
To quit its charge, too soon, in dark despair;
Will ply each mean, and watch th' effect with care:
For should the smallest spark of life remain,
Life's genial heat may kindle bright again.

Rules of the Humane Society for Recovering Drowned Persons, 1767

This is to acknowledge that Dr. James M. Atkins has disclosed no commercial relationships related directly or indirectly to this program. Dr. Atkins will be discussing off label uses in his presentation.

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Case:

Mr. Y is a 54-year-old man who had just cleared security at Love Field and was hurrying to catch a plane when he suddenly collapsed. Security personnel retrieved an automated defibrillator and attached the device. The device delivered one shock after which Mr. Y resumed a normal rhythm. Paramedics arrive four minutes later to find Mr. Y talking to the security personnel. Mr. Y wanted to continue his trip. The personnel argued with him and even threatened to arrest him if he did not go to the hospital. At the hospital, no evidence of anatomical cardiac disease was found. An implantable cardioverter-defibrillator was implanted. Mr. Y continues to do well having returned to his normal activities.

Historical

The first written report of cardiopulmonary resuscitation (CPR) has frequently been attributed to Elisha in the Old Testament:

> 32 *And when Elisha was come into the house, behold, the child was dead, and laid upon his bed*
>
> 33 *He went in therefore, and shut the door upon them twain, and prayed unto the Lord.*
>
> 34 *And he went up, and lay upon the child, and put his mouth upon his mouth, and his eyes upon his eyes, and his hands upon his hands; and he stretched himself upon the child; and the flesh of the child waxed warm.*[1]

This technique did not gain wide acceptance, possibly due to the long response time…two days.

Interest in resuscitation again appeared in the eighteenth century, probably due to the large number of drowning victims along the coast of the British Isles. In 1774 the official reports of the Society for Recovery of Persons Apparently Drowned were published. This detailed report teaches many lessons which are still important. Primarily, that utmost speed is essential if the attempts at resuscitation are to succeed. Detailed, excellent descriptions are given of mouth-to-mouth and mouth-to-nostril breathing. It was suggested in this work "a handkerchief or cloth may be used to render the operation less indelicate." Rescuers were instructed to continue vigorous efforts for two hours before abandoning resuscitation. The techniques were recommended for anyone who collapsed suddenly, not just drowning. One fascinating account describes a child who was successfully resuscitated using "electricity." In one case external cardiac massage was described as follows, "Having no apparatus at hand for inflating the lungs, I availed myself of the natural elasticity of the ribs by pressing forcibly upon the sternum and then suddenly removing my hand…."

In the colonies this was ignored. The discovery and increasing use of tobacco created a totally different approach – rectal insufflations of tobacco smoke. Though very popular for nearly 100 years in the United States, its only lasting contribution was to our slang language. If mouth-to-mouth breathing or the use of tobacco smoke failed, the rescuer was advised to use "a tube to be inserted through the mouth or nostrils to which could be attached a pair of bellows." If this method was not successful, "it may be necessary to make an opening into the windpipe" for insertion of a tube. This eighteenth century report identified five key elements of resuscitation: 1) speed is essential, 2) attempts should be with vigor and not be prematurely abandoned, 3) ventilation must be assured, 4) external compression of the chest should be performed, and 5) electricity may be of value. Tragically these recommendations were lost for nearly two centuries except in the British Navy.[2-3]

Over the next two centuries the techniques regressed with less effective methods assuming the forefront. In 1946 Dr. James Elam, who was later on our faculty until his death, helped bring back the use of mouth-to-mouth ventilation. During the poliomyelitis epidemic in Minnesota, he performed mouth-to-mouth ventilation on several victims transiently due to lack of an adequate number of tank respirators.[4] In the late 1950's external chest compression was reintroduced due to the work of Kouwenhoven, Jude, and Knickerbocker. [5] In 1966 recognizing that there were more than 1,000 pre-hospital sudden deaths per day in the United States, a National Academy of Sciences-National

Research Council Conference on CPR recommended that external chest compression be taught to all health professionals according to the standards of the American Heart Association.[6] Gradually, education was begun not only for health professionals but also in a few limited cases for lay persons. In 1971-1972 Dr. Thomas Burnap, a deceased member of our faculty, chaired the CPR committee of the American Heart Association that set in motion the mechanisms for national conferences on CPR. These conferences created new Standards and Guidelines in 1974, 1980, 1992, and 2000.[7-10]

Background

Sudden death is a frequent occurrence in the United States. Trauma, suicide, and homicide make up a proportion of these incidents of sudden death. However, the greatest proportion of these deaths is cardiac in nature. Even though, cardiovascular disease has had a dramatic decrease in mortality rates over the past 30 years, it still accounts for one-half of all mortality in the United States. Of these deaths, 350,000 are due to sudden cardiac death. The majority, 75-80% of these events occur in patients with known cardiovascular disease while sudden cardiac death is the first symptom in 20-25% of victims.[9-14] Cardiac arrest is the final event in all deaths. Sudden cardiac death makes up about ¼ of all deaths. The majority of these deaths are in patients with coronary artery disease and sudden cardiac death in these victims account for between 1/6 and 1/5 of all deaths.[9-20]

Table 1. Hospital Discharge Survival Rates from Out-of-Hospital Cardiac Arrest

	Survival rate	Survivors	% Survivors
2000 events 1000 no CPR	0	0	0%
1000 with CPR 400 non-cardiac	0.4%	1	1%
600 cardiac CPR 270 PEA or asystole	1.6%	4	5%
330 cardiac CPR VF 132 not witnessed	<1%	1	1%
176 witnessed VF 76 survivors	43%	76	93%

To better understand various reports on resuscitation survival, it is important to understand what the resuscitation rates mean. Most of the reports deal with out-of-hospital arrests. Table 1 shows what happens with 2000 patients to whom the emergency service system responds. About half of the victims have rigor mortis, severe dependent lividity, decomposition, decapitation, brain/cardiovascular injuries incompatible with life, or living wills; no resuscitation attempts are made on these patients. In addition there are other deaths to which EMS does not respond.

	% Survival
All deaths	4.1%
All CPRs	8.2%
All cardiac patients	14%
All cardiac VF	23%
All witness cardiac VF	43%

Table 2. Long-Term Survival from Out of Hospital Cardiac Arrest

When comparing top emergency medical service systems to each other, the initial survival statistics are similar. The greatest differences are in the method of reporting the results. Unfortunately, there has been no consistent method of reporting cardiac arrest survival in the literature. Recently, standards have been developed using the Utstein criteria[21-23]; however, there have been few reports in the literature since these guidelines were developed. Thus, the reader must carefully evaluate any reports to try and understand

what groups are included in the study. Some studies are from specialized hospitals where the results are dependent upon the diagnoses of the patients and on exclusions. For example comparing a cancer facility, a nursing home, and a general hospital would be difficult at best. The use of do not resuscitate orders will also greatly affect the mixture of patients.

Etiology

Whenever autopsy or resuscitated patient series are examined, about two-thirds of patients suffering a cardiac arrest have coronary artery disease. The distribution of coronary artery disease is similar to that seen in patients with stable angina, acute myocardial infarction, or unstable angina pectoris. About 40-50% of patients with any of these presentations will have three-vessel coronary artery disease. Another 30% have two-vessel coronary artery disease, and 20-25% have one-vessel coronary artery disease. Thus, the distribution of coronary artery disease is not different in patients who present with any other coronary syndrome. The majority of sudden deaths from coronary artery disease do not have transmural myocardial infarction. Older studies of patients resuscitated from cardiac arrest showed ECG evidence of infarction in only 16% of patients resuscitated. Using older enzyme criteria with CK and AST, the incidence of infarction was only about 45% of resuscitated patients.[24] Davies and Thomas in a detailed autopsy series found no acute arterial lesion in 19%, plaque fissure only in 7.7%, mural non-occlusive arterial thrombus 43.5%, and occlusive thrombus in 29.8%.[25] Though these findings were poorly understood at the time, our current understanding of coronary syndromes gives us a better understanding of events. Most sudden cardiac deaths are not due to occlusion of a coronary artery with myocardial infarction. Most sudden death is due to plaque rupture with or without mural non-occlusive thrombus. It would be expected that many of these patients would have mild or borderline elevations of troponins similar to what is seen in patients admitted with chest pain. Therefore, it would appear that the major cause of sudden death is plaque rupture with an unstable angina type of syndrome. This syndrome may or may not be symptomatic. It appears that the most frequent mechanism of sudden cardiac death is coronary artery disease with an unstable plaque in the presence of ventricular ectopy. The unstable plaque may be responsible for releasing various factors that alter the fibrillation threshold and leads to lethal ventricular ectopy. This probably helps explain why anti-arrhythmic agents do not reduce the incidence of sudden cardiac death, but anti-platelet and beta-blocking agents do reduce the incidence of sudden cardiac death.

The second most frequent mechanism is an acute myocardial infarction. The remainder of sudden cardiac deaths is due to other forms of heart disease including cardiomyopathies (both hypertrophic and dilated), valvular heart disease, and hypertensive heart disease. Cardiac conduction abnormalities are associated with an increased incidence of sudden death, including the QT prolongation syndromes, the pre-excitation syndromes, and heart block. Many drugs can also cause sudden death by various mechanisms. Metabolic causes, including hypokalemia, hyperkalemia, and hypomagnesemia, also can play a role. In some cases no etiology can be found. Since the majority of sudden cardiac death victims have coronary artery disease, statistically the major risk factors for sudden cardiac death are the same as the risk factors for coronary

artery disease. In addition, other risk factors include ventricular ectopy, poor ventricular function, conduction abnormalities, and left ventricular hypertrophy.[9,11-20,24-29]

Mechanisms and Rates of Survival

In patients with cardiovascular disease, the dominant mechanism of cardiac arrest is ventricular fibrillation or ventricular tachycardia. Though the exact incidence is unknown, estimates range from a 60-90% (with most estimating 85%) incidence of ventricular fibrillation, as the mechanism in patients with cardiovascular disease. As the population of victims has aged over the last three decades, the age-specific incidence has declined; however the total incidence has remained constant. In 1976 the peak age of events was age 53-55 years; by 1993 the peak age had climbed to 65-71 years; in 2001 the peak age is 71-80 years. In older patients more PEA or asystole has been observed. A second major mechanism is pulseless electrical activity (PEA). PEA is a common mechanism in patients who have hypovolemia or hypoxia. PEA is the most common presentation of traumatic cardiac arrests. In patients with very severe cardiovascular disease and end-stage heart failure, PEA is more common. Asystole is usually a secondary arrhythmia. Primary asystole can occur particularly in patients with infra-His heart block (Mobitz II). However, the vast majority of patients with asystole probably had ventricular fibrillation or PEA first, then after 20 to 30 minutes became asystolic.[9,15-19,27-29]

Patient survival from cardiac arrest is primarily from victims of ventricular fibrillation or ventricular tachycardia. Studies show that 95-97% of survivors at hospital discharge had ventricular fibrillation or ventricular tachycardia as the mechanism of arrest. Survivals of up to 70% have been seen in the pre-hospital arena. Survival rates of greater than 90% have been achieved in the coronary care unit when cardiac arrest was not associated with preexistent shock. Survival rates from asystole and PEA have remained dismal at less than 5%. Using a computer model of ventricular fibrillation with input from various databases, it has been shown that survival declines 7-10% per minute for each minute from the time of collapse until successful defibrillation.[9,15-19,27-31]

Treatment – Chain of Survival

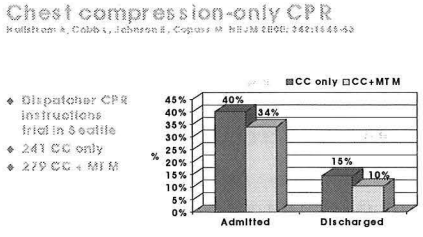
When studies of successful resuscitation from cardiac arrest are examined, there are four dominant factors that differentiate survivors from non-survivors. These factors are 1) time, 2) defibrillation, 3) drugs (particularly epinephrine), and 4) CPR. Time to defibrillation is the most important determinant of survival. Time to epinephrine and time to CPR are also important determinants. CPR mainly widens the window of time for which defibrillation or epinephrine can be effective. Thus, CPR should be looked upon as a holding action, a losing holding action that merely prolongs the window of opportunity; though recent evidence has suggested that it may play a special role in certain cases. Most of the long-term survivors of cardiac arrest are 1) victims who had a witnessed cardiac arrest from ventricular fibrillation or ventricular tachycardia, 2) who had CPR begun within four minutes, and 3) who had defibrillation and advanced cardiac life support within seven to eight minutes. The American Heart Association has identified the chain of survival with four steps – early access, early CPR, early defibrillation, and early advanced cardiac life support.[10]

Early Access

Rapid recognition of the problem and activation of the emergency medical service (EMS) system is essential. Whenever unresponsiveness is recognized outside the hospital, EMS should be activated through the 9-1-1 systems. Inside the hospital, the call for assistance should be made to the appropriate communication point for the hospital (code team, code blue, doctor heart, etc.). One problem outside the hospital is that 9-1-1 is not universal. In 1993, only four states had universal 9-1-1. By 1999, 92% of the population was covered by 9-1-1 with seventeen states having universal 9-1-1. The events of September 11, 2001 have added renewed impetus to the goal of having universal 9-1-1 in the United States. In the urban areas, enhanced 9-1-1 has become the rule. Enhanced 9-1-1 uses caller ID that cannot be blocked and gives not only the calling telephone number but also the address of the telephone. Enhanced 9-1-1 has aided in the rapid and proper dispatch of emergency equipment and personnel. One problem with enhanced 9-1-1 is the advent of cellular telephones. Cellular telephones have not had location identification and are now commonly used for reporting emergencies. The FCC has enacted rules that will require that telephones provide location information to the 9-1-1 centers. This technology can provide location of the cell telephone within 100 feet. The telephone companies have asked for waivers to delay full implementation of these requirements until the end of next year; however, homeland security issues have placed pressure on the FCC and telephone companies to accomplish this in a shorter period of time.

Rapid recognition is also a problem. If the victim is active and standing or walking in a public area, recognition of the event is very fast. However, if the victim is seated and inactive, recognition may be delayed. Obviously, if there is no one else present, then recognition is extremely delayed.

Figure 1. Dispatcher Assisted CPR[32-33]



Training of dispatchers has also changed markedly in the last few years. The dispatchers are taught how to properly interrogate the caller to find out exactly what is happening. The dispatcher can also instruct the caller in the proper methods of performing CPR. One interesting variation is chest compression only CPR as shown in Figure 1.[32-33] This study compared two strategies for performing dispatcher-assisted CPR. When the dispatcher recognized a cardiac arrest, the dispatcher talked the potential rescuer through the steps of CPR. In one group, chest compression only was utilized while in the other group all of the steps of ventilation and then chest compression were utilized. The instructions were simpler in the chest compression only group. When analyzing the time to first chest compression, it was 1.4 minutes faster in the chest compression only group. To also instruct in ventilation, required more instructions and more questions from the rescuer. It should also be noted that ventilation might not be necessary in the first two to three minutes following a cardiac arrest from an arrhythmia. The heart stops suddenly; the blood is still oxygenated. As there is no flow, the blood remains oxygenated. After chest compressions are begun, the oxygen tension

falls in the blood. There is still oxygen trapped in the lungs and there will be some gas exchange during chest compression even though there is no ventilation. There may be sufficient trapped oxygen that will allow for some oxygen transport for the first two to three minutes. This may explain why the chest compression method worked for this particular group of victims. It should not be generalized however; if the event is more prolonged, ventilation may be required. Also if ventilation can be provided in a more rapid manner, it may also be beneficial. The main difference was the 1.4-minute delay offset the benefits of ventilation.[32-33]

Though dispatchers trained to provide telephone instructions used to be uncommon, many states now require trained dispatchers. Texas is one of those states with this requirement. All of the area fire services in Dallas County provide this type of assistance.

Early Cardiopulmonary Resuscitation (CPR) – Basic Life Support (BLS)

Early initiation of CPR increases the victim's chance of survival by widening the window of opportunity for definitive therapy. CPR should be begun promptly and should continue until definitive therapy can be utilized. If a defibrillator is present and the patient is in ventricular fibrillation or ventricular tachycardia, immediate defibrillation should be accomplished. In the first few minutes CPR should never delay defibrillation. Mass training of CPR had increased the number of rescuers performing CPR during the 1970's and early 1980's. However, the fear of AIDS and other communicable disease has led to a decline in bystander or citizen CPR today. Recent studies have shown that bystanders performing CPR were related to the patient or were friends of the patient. It has become rare for a layperson to do CPR on a person they do not know. Hence, emphasis for training should be on family members and friends of patients who are at risk.

Because of the fear of AIDS and other communicable diseases, ventilation was made optional for the lay-rescuer. The only data to support this was the study mentioned earlier concerning dispatcher-assisted CPR. This makes some rational sense and does not appear to alter outcome for the first three to four minutes after an arrest. This may well increase the number of lay-rescuers who are willing to perform CPR. Another advantage is that compression only CPR may also be able to be taught over the television, as it is a very simple technique

Another major change is in checking pulses for CPR. Studies of lay-rescuers found that they were unreliable in determining whether a pulse was present or not. Table 3 shows the results from two different studies of the accuracy of pulse checks in lay-rescuers. Because of this finding and the added time to teach and for the lay-rescuer to

Table 3. Sensitivity, Specificity, and Reliability of Pulse Check as a Diagnostic Test[34-36]

	Pulse is Present	Pulse is Absent	Totals
Rescuer thinks pulse is present	81	6	87 Positive predictive value = 93%
Rescuer thinks pulse is absent	66	53	119 Negative predictive value = 45%
Totals	147 Sensitivity = 55%	59 Specificity = 90%	206 Accuracy = 65%

perform pulse checks, it was recommended that this be deleted from the lay-rescuer curricula. It is still recommended for the professional rescuer to perform pulse checks. In place of pulse checks, it is recommended that the rescuer look for signs of life. These include respirations, though there is the potential for confusion with agonal respirations, responsiveness of the patient, and movement of the patient.[34]

The rate of chest compressions has been increased to 80-100 compressions per minutes. It has been observed that coronary and cerebral flow increases with each chest compression over the first minute and then plateaus. Pausing for ventilation causes the coronary and cerebral flows to fall to zero and the rescuer must start over. Therefore, attempts have been made to reduce the number of pauses for ventilation in order to maintain coronary and cerebral blood flow at as high a flow as possible. There are three basic scenarios that are used. In performing CPR 1) if the patient is not intubated, there are two potential methods that can be employed. The pauses for ventilation should be minimal. It is recommended that whether there is one or two rescuers, the compression to ventilation ratio be 15 compressions: 2 ventilations. This allows for a higher coronary and cerebral blood flow during CPR. The ventilations should each be for about 2 seconds. 2) If the lay-rescuer does not perform ventilations then chest compressions should be at a rate of 100 per minute with no pause. 3) The third method is when a patient is intubated and there is a closed system. With a closed system it is recommended that there are 5 compressions: 1 ventilation; however there is no pause for ventilation. Ventilation is forced in after the fifth down stroke. This maintains a high coronary and cerebral blood flow. It has been shown that there is adequate ventilation of the patient using this method. It does take some degree of skill to successfully ventilate a patient when there is no pause for the ventilation. Table 4 shows an outline of the techniques for both professional and lay-rescuers. [34]

Table 4. Technique of Cardiopulmonary Resuscitation[34]

	Professional Rescuer	Lay Rescuer
Assessment: Determine unresponsiveness; Shake and shout	Yes	Yes
Activate EMS: Call 9-1-1 or code	Yes	Yes
Airway: Position the victim and open the airway by head tilt-chin lift or jaw-thrust maneuver	Yes	Yes
Breathing: Assess breathing to see if it is absent or inadequate	Yes	Yes
• Perform rescue breathing if unresponsive and not breathing • Be sure the victim's chest rises with each breath • After initial two breaths, assess for signs of circulation	Yes	Optional
Circulation: Check for signs of circulation		
• After initial breaths -- normal breathing, coughing or moving	Yes	Yes
• Check carotid pulse for up to 10 seconds	Yes	No
• Locate proper hand position, perform 15 compressions and continue 15:2	Yes	Yes
Reassessment: After 4 cycles	Yes	Yes

Another change is in the tidal volume of the ventilations. It is recommended that without oxygen supplementation, the tidal volume should be 10 mL/kg (700-1,000 mL).

If oxygen supplementation is present, a smaller tidal volume of 6 to 7 mL/kg (400-600 mL) can be utilized. [34]

Adjuncts for CPR

A number of adjuncts have been developed to aid CPR and to improve the results. One of these methods is what is called active compression-decompression CPR (ACD). It has also been called the plumber's helper CPR. This is done by placing a device over the lower sternum that is somewhat like a plunger, which seals to the chest. You press down on the device to compress the chest. You then lift on the device to expand the chest. This augments filling of the chest with blood after cardiac compression by creating a negative pressure in the chest. In animal models that were intubated, it has been shown that this device will allow for adequate ventilation without using assisted ventilations. Several studies have shown that the device can increase coronary perfusion pressure. One problem with the technique is rapid rescuer fatigue due to the lifting. There have been six studies performed with this device.[37-42]

Table 5. Randomized Trials of Active Compression-Decompression CPR vs Standard CPR[37-42]

	Number Patients		ROSC		24 hr Survival		Hospital Discharge	
	ACD	Stand CPR	ACD	Stand CPR	ACD	Stand CPR	ACD	Stand CPR
Cohen[37]	29	33	62%	30%*	45%	11%*	7%**	0%
Lurie[38]	53	77	45%	31%	40%	26%	23%	17%
Tucker[39]	25	28	60%	32%*	48%	21%*	24%	11%
Schwab[40]	414	446	17%	20%	16%	20%	5%	7%
Plaisance[41]	254	258	45%	30%*	26%	14%*	5.5%	1.9%*
Plaisance[42-43]	373	377	31%	23%*	23%	14%*	6%	2%*

* statistically significant $p<0.05$
** 6 patients were alert at 24 hours but were made DNR due to cancer
ROSC – return of spontaneous circulation

Five of the six studies were either positive or had a trend towards being positive. Only one study was negative with a negative trend. Overall, the data is suggestive but not adequately proven. However, there are some interesting findings in these studies. Many of the long-term survivors originally had asystole or PEA. As this group normally has a very poor survival, any improvement is significant. The group that had improved survival was ones with very long cardiac arrests with resuscitation times over 15-10 minutes in several of the studies. The other item of interest is that there was a trend in several of the studies with better neurological outcome over the next year. If a larger study supports these findings, this may be a significant advance in resuscitation.[37-42]

Another device has been utilized with both standard CPR and active compression-decompression CPR. This device is an inspiratory impedance threshold valve (ITV). This device works by slowing inspiration. As the chest wall has natural elastic recoil, this creates a transient negative pressure in the chest during inspiration; this negative pressure augments blood return to the chest and increases cardiac output. This device has

shown in animal studies to greatly increase coronary and cerebral perfusion with both standard CPR and ACD CPR. One small study in humans showed that the combination of ACD-CPR with ITV increases flow more than either technique alone and had a trend to higher survival; ROSC was 2 of 10 patients with ACD-CPR only and 4 of 11 patients with ACD-CPR plus ITV. As this is a simple technique in an intubated patient, further studies are warranted.[44-46]

Another device has been described. This is a double plunger device called "Lifestick". There are two plungers that seal on the chest and on the abdomen. Two operators rock the device so that there is abdominal decompression during chest compression and abdominal compression during chest decompression. This device has been shown in porcine models to significantly increase hemodynamic variables and vital organ flows before epinephrine administration.[47]

A CPR vest has also been studied with significant increases in vital organ blood flow and showed improved ROSC in animal models.[48] Human studies were positive. However, this study was performed late during cardiac arrest at Johns Hopkins. Due to the FDA moratorium on cardiac arrest research, this study has not been completed.

These three devices have not been adequately studied in the last ten years. The reason is a moratorium that occurred for several years in the United States. Even though the moratorium has been ended, the requirements for performing research on patients in the United States are problematic. There are three mechanisms for performing these types of studies. 1) Written informed consent can be obtained prior to the research: this could be accomplished by having all admissions to the hospital sign a consent to perform research in case they have a cardiac arrest. This would be extremely difficult and many would decline; it would be hard to keep track of who had signed and who had not signed. 2) The family of the victim could be asked to sign consent after the fact if the patient did not survive with intact neurological function. 3) Community consent could also be obtained using a public education program and community hearings. To date only one study using the last method has been undertaken. Several other attempts have been withdrawn due to the financial impact of this method. There is a need for research into cardiac arrest management. However, most research will be done in Europe and Asia due to the restrictions in the United States. Most device and drug research has been moved overseas and many of the US investigators have moved to other fields leaving only animal research in the United States except for the one trial that is underway.

Early Defibrillation

Early defibrillation is also an important link in the chain of survival. As most of the survivors of cardiac arrest originally had ventricular fibrillation and defibrillation is the only definitive treatment for ventricular fibrillation, it is the most important link in the chain of survival. In fact if time to defibrillation is short, the links of early CPR and early advanced cardiac life support may not be needed to have return of spontaneous circulation. The emergency response system has changed drastically in the last decade. In 1993 it was estimated that less than 25% of ambulances had defibrillators. Today almost every ambulance in the United States has a defibrillator and defibrillators are usually found on most fire department vehicles and in many police cars. It is not unusual to have three or four defibrillators available at the scene of an out-of-hospital cardiac arrest.

Table 6. Fire Department Use of AEDs[49]

	AED	Control
Number of patients	169	200
Number of patients with VF	74	
Number shocked	72 (97%)	
Episodes of VF	115	
Episodes of VF shocked	104 (90%)	
ROSC	21 (12.4%)	10 (5%)
Long-term survivors	19 (11.2%)	6 (2.6%)

The defibrillators on ambulances tend to be standard defibrillators, while the defibrillators on fire vehicles and police cars tend to be AEDs (automated external defibrillators. One of the earlier programs with defibrillators on fire engines was here in Dallas. We placed AEDs on 10 fire engines around Dallas. The sites were determined by using prior statistics to find fire districts that had a high number of cardiac arrests and where the fire engine arrived at least two minutes prior to the ambulance. The control was cardiac arrests in the same fire districts before, during, and after the use of AEDs. There was a significant improvement in survival both short-term and long-term.[49] It should be noted that the same results would not have been obtained in any other fire districts. Twenty-eight of the 56 fire districts had an ambulance in the same fire house as the responding fire engine and would have been on the scene at the same time or before the fire engine with a standard defibrillator on board. The remaining 8 fire districts had very few events and would have not been statistically significant.

Kellermann[50] did an almost identical study in Memphis and found no benefit. In Memphis, AEDs were placed on the 10 busiest fire engines. Those fire engines had ambulances in the same fire district. Usually the fire engine arrived simultaneously with the ambulance or the ambulance arrived first. In comparison, our study in Dallas showed that the fire engine was on the scene more than 2 minutes prior to ambulance arrival 62.7% of the time. Several years ago we placed AEDs on the cardiac step-down unit at Parkland Memorial Hospital. We found that they made no difference as physicians arrived at the same time with a standard defibrillator. The AEDs did make a difference in areas where there were no physicians present. Thus, an AED must arrive on the scene prior to the arrival of a standard defibrillator and trained personnel to be effective. When trying to look at the effectiveness of an AED, one must consider the frequency of events and the method in which the device will interact with the rest of a system. An AED that arrives at the same time as a standard defibrillator with trained personnel will not increase survival; however, an AED that will be present at least 2 minutes prior to a trained team with a standard defibrillator will make a difference with the magnitude of this difference being determined by the incidence of cardiac arrest.

The placement of AEDs has markedly increased in the past five years. Since they are computer operated, they require minimal training (usually takes two to six hours depending on whether or not the person has been trained in basic CPR). The devices generally only have three controls and automatically instruct the patient what to do from attaching the electrode through defibrillating the patient. The fire service has deployed these devices extensively in the United States. But there have been other groups of public service first-responders that have begun using the devices. In Rochester, Minnesota the police have been using the devices. This is a small town with a very rapid response time by police and a slower response time by fire and ambulance. Of 42 patients with ventricular fibrillation, bystanders witnessed 35 events. Fourteen (38%) regained ROSC and did not require advanced life support intervention; all 14 patients

were discharged home alive. Of the remaining 21 witnessed events requiring advanced life-support and epinephrine, only two (9.5%) survived to hospital discharge.[51-52]

It is apparent that an organized response team can make a difference. The problem with organized response teams is the response time to the patient. As stated above, the chance of surviving an episode of ventricular fibrillation falls by 7 to 10% for every minute from collapse until they are defibrillated. If the event is witnessed with something dramatic, it still takes the bystander about a minute to make the call. It takes dispatch another minute to send the equipment. It takes the response system a period of time to respond. In rural areas, small towns, and suburbs, police can often respond in three to four minutes. It still takes another minute to get the equipment and attach it to the patient. So the earliest a response system can attach a defibrillator is 6 minutes after collapse in the best of circumstances. This means that survival is now in the 50% range.

In an urban area, the fire service usually has a faster response than police and is therefore the better first responder. In Dallas, our fire response time is about 4 minutes for fire engines and 5 minutes for ambulance, while the police response time is about 10-12 minutes. Thus, fire is the better first responder in Dallas. Some cities have response times for first responders of 10-15 minutes and usually have rare survivors from cardiac arrest. It is obvious that the logistical problems have limited the usefulness of these technologies.

In certain venues the response time is incredibly long. For example, international air travel could have response times of several hours. For this reason, Qantas Airlines, which transports passengers on very long flights, placed AEDs on their airplanes beginning in 1992.[53] The AED was attached to 109 different victims (the majority did not have a cardiac arrest). They had 46 cardiac arrests in which the AEDs were used. Twenty-seven events occurred in-flight; only 46% were witnessed. Of the twenty-seven events, only 6 had ventricular fibrillation and 2 survived. There were also 19 events in the terminals in which the flight attendant ran back onto the plane and got the AED. Seventeen of the 19 patients had ventricular fibrillation; four survived. The economic impact was such that the airline made a profit from the program. The plane was not diverted except when there was a resuscitated victim and this greatly reduced the operating costs of the airline, as diversions of international flights are extremely expensive due to all of the secondary problems that arise from diversion.

This data helped push the US Congress into studying the problem and recommending that AEDs be available in all airports and on most flights. American Airlines began a similar program in 1997. The device was attached to 200 patients (9 in the terminal). Of these 99 patients had lost consciousness and 36 victims had a documented cardiac arrest. Fourteen of the patients with cardiac arrest had ventricular fibrillation. Thirteen of the 14 patients with ventricular fibrillation were defibrillated with one shock. The remaining patient was not shocked at the request of the family. There was a 40% survival in this group of victims as reported from this institution by Page et al.[54] These two studies have encouraged most of the US and many foreign carriers to place AEDs on their aircraft. The FAA has mandated the equipment on certain flights.

Officials in Chicago looking at the results of these two airline studies decided to place 33 AEDs at O'Hare and 7 AEDs at Midway airports. They have recently reported their results. There were a total of 21 cardiac arrest victims at the two airports. Three

had non-ventricular fibrillation rhythms and none survived. Eighteen had ventricular fibrillation and were defibrillated with the AEDs. Eleven of the 18 regained consciousness and were neurologically intact. Ten (56%) were alive at one year. It should be noted that Good Samaritans, not the trained rescuers, shocked 16 of the 18 victims. Individuals that had never used an AED before and had not been trained shocked seven of the victims. Seven of the survivors were resuscitated with one shock and four of the survivors required 2 or 3 shocks.[55] In comparison, the survival rate in the city of Chicago is 2%. This shows the effect of AEDs at the site of event. As stated earlier, logistics are very important. These save rates are higher than those that can be achieved by even the most sophisticated rescue systems. This information led to the FAA requiring that defibrillation be available at all commercial airports in the United States.

Casinos[56] are also sites that have a significant incidence of cardiac arrests and there have been two major studies in casinos.[57-59] Security personnel were trained to use AEDs in ten different casinos in Nevada and Mississippi. Of 148 patients with cardiac arrest, 109 patients had ventricular fibrillation and 90 of the 109 were witnessed events. Fifty-three (36%) of the ventricular fibrillation and three (2%) of the non-VF patients survived to discharge. Those patients who were defibrillated in 3 minutes or less had a survival of 74% and those who had a witnessed event with defibrillation delayed past three minutes had a 49% survival.[57] Another study in Windsor, Canada showed that of 23 arrests in a casino, 21 had VF. Fifteen (71%) of the VF patients survived. In the City of Windsor only 5% survived.[59] It is obvious from the data in airports and casinos that early defibrillation by personnel present at the site can salvage more lives than efficient emergency medical service systems.

On November 13, 2000 President Clinton signed into law House Rule 2498, the Cardiac Arrest Survival Act, which expanded the availability of AEDs. This bill and the executive order that accompanied it requires that all federal buildings and buildings that are leased by the federal government should have defibrillators.[60] Many office buildings have also added AEDs. While AEDs have resuscitated a large number of individuals in airports and casinos, the impact in general office buildings is not known.

To evaluate the potential efficacy in other sites, it is important to understand where cardiac arrests occur. First, it is important to know the age of the cardiac arrest population. The age of the patients with cardiac arrest has steadily increased. In Dallas in 1976 the peak age for cardiac arrest was between 53 and 56 years. By 1993 the peak age had increased to 65 to 71 years. Figure 2 compares the age distribution for three years from 1992 through 1994 to the last three complete years 1999 through 2001. The peak age is now in the 71 through 80-year range. The absolute number of events has declined in victims under the age of 40. This decrease in absolute number of events is in spite of an increase in the population and a large growth in the younger ages in Dallas. There has been an incredible increase in the older populations in a short period of time. There has been a doubling of events in the oldest two decades of patients. Figure 3 shows that there is almost an equal number of victims 65 years and older as compared to those under 65 years of age during the year 2001. As victims 65 and older make up half of the population, then sites where those over 65 years are present are the most likely sites to have cardiac arrests. Further, sites where older individuals are active are the sites

Figure 2. Age Distribution of Cardiac Arrests in Dallas

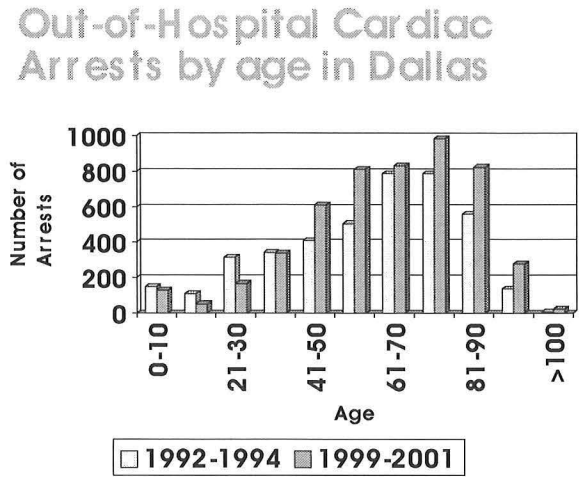
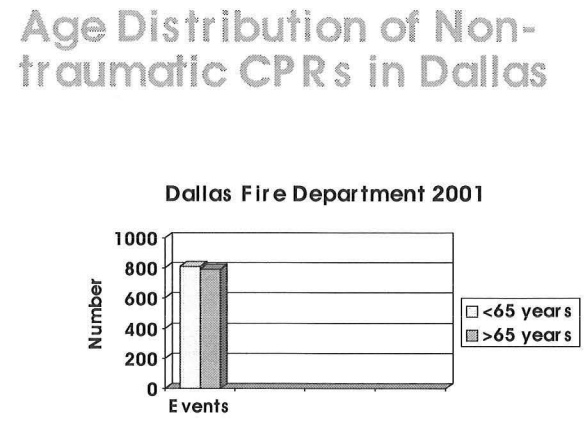


Figure 3.



where witnessed events are most likely. There have been three major studies of the site of cardiac arrests locations.[61-63] The majority of cardiac arrests, between 80 and 85%, occur at home. Most of the events occur in older individuals who are usually retired. Another large group of victims are patients with chronic disease who are at home. Even in the healthy population, more events occur at home than in public. Hence only about 16% of events are in public locations. In public locations the most likely sites are where older victims are active. Thus, casinos, golf courses, malls, senior recreation centers, airports, and parks are the non-medical sites where events are most likely to occur. Even if AEDs were widely placed like fire extinguishers, and the system was very efficient only about 20,000 lives could be saved; however, this assumes that all public places would have the same results, which is not likely. In Dallas there are only about 30 events per year in all of the high-rise office buildings that do not have a health care facility in the building. This approach will save a substantial number of lives, but it will not affect the vast majority of patients with events.

Another approach is to try and have devices at locations where the potential victims live. There is a large study of public access defibrillation being conducted at the

present time. The National, Heart, Blood, and Lung Institute of the NIH, the American Heart Association, and a number of manufacturers of the devices jointly sponsor this study. This study pairs large apartment complexes and other public buildings to have AEDs with CPR training or CPR training only; the sites were randomly assigned. The study is on going. Another possibility is the use of AEDs in potential victims' homes. This has been attempted on a very limited basis and did not meet with success. One major problem is for the device to be effective the event must be witnessed. At home while sitting in an easy chair or asleep, who is going to be the witness? Many times the spouse or other family member cannot awake the victim sometime later; thus the event is not witnessed. This represents a very significant challenge.

An alternative approach has been to place an implantable cardioverter-defibrillator (ICD) in high-risk patients. The AVID trial showed that ICDs reduce the mortality as compared to anti-arrhythmic drug (AAD) therapy in patients with sustained ventricular tachycardia or ventricular fibrillation.[64-65] The study showed that survival was better with an ICD than with an anti-arrhythmic drug (Table 7).

Table 7. Results of the AVID Trial[64]

Survival	ICD	AAD
1 year	89.3%	82.3%*
2 year	81.6%	74.7%*
3 year	75.4%	64.1%*
		* = $p<0.05$

This study shows a potential impact. However, the patients in this study had sustained ventricular tachycardia or fibrillation and had undergone an electophysiologic study. This is not practical or cost-effective for the population at large. Unfortunately, only a few potential victims can be identified by this technique.

Figure 4. Framingham Risk Profiles

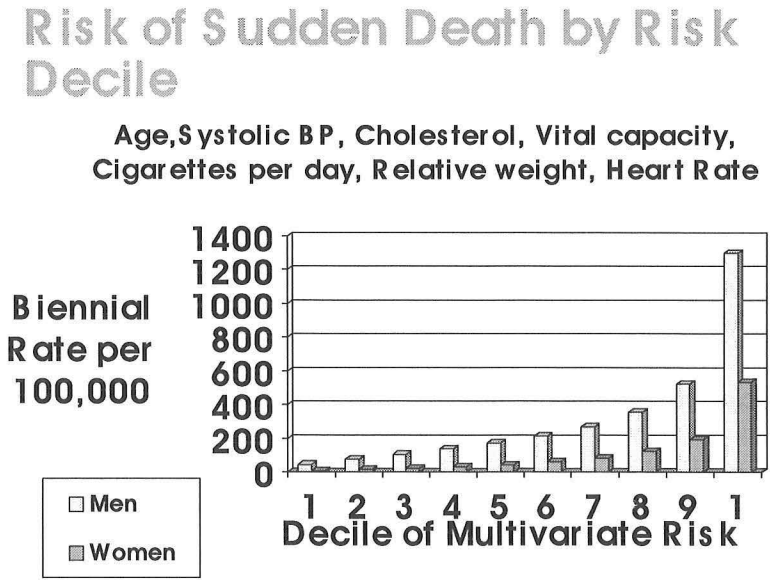


Figure 4 shows the magnitude of the problem. This is the risk of sudden death by risk decile using risk factors that are easy to obtain. If you examine the highest risk decile, only 41% of cardiac arrests in men and 50% in women are in that decile. Thus, the majority of sudden deaths are in lower risk deciles. Even the lowest risk decile has a

significant number of events. If you placed ICDs in the highest risk decile, the costs would be about $2 billion. This would calculate to a cost to save one person in the biennium of $3.7 million for men and $11.8 million for women. Obviously, this is not a viable method of trying to reduce the risk. Thus, all of the approaches have marked limitations. Further studies are needed to find an effective method to reduce the incidence of sudden death. Until that time widespread use of therapies that can prevent cardiovascular events will have to be utilized. These include beta-blocking agents, cholesterol lowering therapy, aspirin, ACE inhibitors, and risk factor reduction.

The King County EMS system has reported that survival rates were better when they did one minute of CPR prior to defibrillation in victims that have been down for more than 5-6 minutes. This is merely an observation that needs further study.

Early Advanced Cardiac Life Support

Early advanced cardiac life support (ACLS) is the final link in the chain of survival. However, it may be the least important link. Most of the survivors regain ROSC prior to the advent of ACLS in many of the trials of early defibrillation. Though ACLS makes a difference in a small number of victims, the vast majority of survivors are resuscitated prior to drug therapy. As the numbers of survivors are very small who required ACLS, it is difficult to effectively evaluate the interventions. Though ACLS increases survival, it is not clear which interventions aid and which do not as many interventions are done about the same time

Vasoactive Drugs

Many different vasoactive drugs have been evaluated. Drugs with inotropic, chronotropic, and vasoconstrictive properties have been advocated for the treatment of cardiac arrest. These drugs have been utilized empirically or based upon animal data. Definitive human data is lacking, though the data is suggestive of benefit of drugs with vasconstictive properties.

Epinephrine is the drug that is most commonly used during resuscitation. The beneficial effects of epinephrine in resuscitation were described in 1896.[67-68] As early as 1906 Crile and Dolley described the importance of keeping diastolic pressure above 30 and preferably above 40 mmHg.[69] The only way to keep the diastolic pressure at these levels were through vasoconstriction. During CPR the diastolic pressure tends to equal the venous pressure unless a vasocontrictive drug is being administered. It was thought that the inotropic and chronotropic effects of these drugs were important; however, it has been shown that only the vasoconstrictive effects are responsible. With vasoconstriction there is a transient decrease in perfusion to most of the body, but a substantial increase in diastolic pressure.[70-71] Without an increase in diastolic pressure, there is virtually no blood flow through the coronary arteries during CPR. Vasoconstriction causes an elevation of the diastolic aortic pressure that increases coronary blood flow. This coronary blood flow is probably essential to allow restart of the heart after the victim has been down for a prolonged period of time. The importance of the vasoconstrictive properties of epinephrine has been pointed out in animal models using blocking agents.[72] In these animal models, when alpha blocking agents were used with epinephrine, resuscitation failed; but when beta blocking agents were used with epinephrine, the resuscitation was uniformly successful. This points out that it is the vasoconstriction that

is important not the inotropic and chronotropic effects. Drugs whose main action is inotropic and/or chronotropic, such as isoproterenol, dobutamine, or calcium salts, have been shown to be useless and probably harmful.[67-77] Alpha receptor agonists, such as phenlyephrine or methoxamine have been shown to be as effective as epinephrine and all three are significantly better than control.[67-77] Non-adrenergic vasoconstrictors have also been shown to be of benefit. In animal models, angiotensin II was as effective as epinephrine in restoring ROSC.[78] Vasopressin has also been studied and will be discussed later.

Evidence shows that vasoconstrictors increase both cerebral and cardiac blood flow during CPR, particularly well studied with epinephrine. It appears that the effects on cerebral and cardiac blood flow are more important than any of the beta effects of epinephrine. The minimum dose of intravenous epinephrine is 1 mg for average size adults or 0.01 mg/kg for children or very large adults. The dose has been empiric in nature. In animal studies, higher doses of epinephrine have been shown to have a higher rate of ROSC. Human studies are shown in Table 8.

Table 8. Comparisons of High Dose and Standard Dose Epinephrine

	Admission		Discharge	
	Stand epi	High epi	Stand epi	High epi
Brown[79]	22%	22%	4%	5%
Stiell[80]	23%	18%	5%	3%
Callaham[81]	10%	18%	1%	2%

As can be seen in these three studies that contained a total of 2,674 cardiac arrest victims, they did not show a major improvement in survival with high dose epinephrine. There was a trend to a higher hospital admission in one study and a lower hospital admission in another study; none of the studies showed any evidence of increased survival. The studies did show that high dose epinephrine had a higher ROSC in the field, but the benefit was gone by the time the ambulance arrived at the hospital.[79-81]

Table 9. Pediatric Comparisons of Epinephrine Dose

	ROSC		Discharge	
	Stand epi	High epi	Stand epi	High epi
Carpenter[82]	70%	58%	23%	26%
Dieckmann[83]	8%	8%	2%	2%

There was considerable enthusiasm in pediatrics for high-dose epinephrine; however when comparison studies were performed, there was no advantage to high dose epinephrine. The Carpenter study was performed in-hospital while the Dieckmann study was out-of-hospital.[82-83]

The bottom line with epinephrine is that there is no evidence than any dose other than the standard dose of epinephrine has any benefit. So it is recommended that adults be given 1 mg of epinephrine every 3 to 5 minutes during cardiac arrest and that children be given 0.01 mg/kg doses. The other side of the coin is that there does not appear to be any harm from using high doses of epinephrine.

Vasopressin has recently been studied in some degree of detail. In physiologic doses, vasopressin is an antidiuretic hormone. In very high doses it is a non-adrenergic vasoconstrictor that works through the V_1 smooth muscle receptor by a direct action. It is a potent arterial constrictor in these pharmacological doses as well as causing many other effects. It has been used clinically to stimulate uterine contractions and for control of bleeding from esophageal varices. It has a half-life of 10-20 minutes in animal models.[84]

Lindner reported in 1996 observations in patients with out-of-hospital cardiac arrest. They compared blood samples from those patients who regained a pulse versus

those that did not regain a pulse. They found that there was no difference between the two groups in the blood levels of endothelin, epinephrine, norepinephrine, or cortisol. However the found that those who regained a pulse had between a two and three-fold elevation of their blood levels of arginine vasopressin and ACTH.[85-86] With this information, the authors have embarked on detailed studies of vasopressin in many different porcine models.

In porcine models of ventricular fibrillation, they have shown that vasopressin like epinephrine has increased myocardial blood flow and median frequency of the fibrillation.[87-88] In animal models of arrest from ventricular fibrillation, asphyxia, and vasodilatory arrest (PEA), there have been studies that showed improved flows to the heart, brain and other potential benefits.[89-102] In porcine models of pediatric arrest, they have also shown the potential benefit.[103-104] Combinations with epinephrine, dopamine, nitroglycerin, endothelin have been studied with improvements in organ flows.[93,105-107] Thus it appears that vasopressin is effective in animal models. Vasopressin may have slightly better hemodynamics than epinephrine in medium length arrest models. When the cardiac arrest is due to asphyxia and more prolonged, the combination of vasopressin and epinephrine is better than either drug alone.[93] However, it should be noted that many drugs have looked better in animal models and this has not held up when these drugs are used in humans.

Table 10. Vasopressin and Epinephrine in Cardiac Arrests

	# patients	1 hour		Discharge	
		Epinephrine	Vasopressin	Epinephrine	Vasopressin
Lindner[108]	40	35%	70%	15%	40%
Stiell[109]	200	35%	39%	14%	12%

To date there have been two small randomized studies with vasopressin versus epinephrine as shown in Table 10. In the Lindner study, the trend favoring vasopressin at one hour had a p value of 0.06. There were no differences at discharge or in the larger study. The evidence does not yet support that vasopressin is superior to epinephrine. The correct use of vasopressin remains to be determined. There is also no evidence that epinephrine is superior to vasopressin. Vasopressin can be given down an endotracheal tube or through an intraosseous infusion.

Endothelin-1 has also been used in a canine model with improved hemodynamics but worse post-resuscitation outcome[110] Recently, alpha-methynorepinephrine, a selective $alpha_2$-adrenergic agonist has been shown to be as effective as epinephrine but with less infarction and better myocardial function in a rat model.[111]

Even though there has been a tremendous amount of work on vasoactive drugs during resuscitation, their true benefit has yet to be determined. There is probably a need for a placebo controlled large trial in humans to determine what the role of the agents should be if any. However, the FDA would probably not allow such a study as they would not feel that a proper consent could be obtained.

Anti-arrhythmic drugs

Anti-arrhythmic agents utilized during cardiac arrest can only be studied in humans. There is no effective animal model to evaluate the efficacy. Most of the use of anti-arrhythmic agents has been empirical.

Lidocaine is the most commonly used anti-arrhythmic agent in ventricular fibrillation. However, there are no randomized trials to support its use. It does not appear to cause harm, so it is used in protracted ventricular fibrillation. The doses used are usually 1.5 mg/kg, which can be repeated once.[112] Bretylium, which is no longer available, was shown to be equal to lidocaine and slightly better at terminating ventricular fibrillation; however, the patient frequently converted to asystole.

Magnesium sulfate has been recommended by many for the treatment of refractory ventricular fibrillation. There have two trials looking at the efficacy of magnesium sulfate. Miller showed that 5 grams of magnesium sulfate did not improve survival in a small study of 62 patients. Survival was 5.2% with magnesium sulfate and 4.5% with control[113] The Duke house staff performed a study with 2 grams of magnesium sulfate versus control in 156 patients. They showed that ROSC with magnesium sulfate was 54%; the 48% ROSC in control patients was not statistically different. Survival to discharge was 21% in both groups.[114] Magnesium sulfate is not recommended for routine use in ventricular fibrillation.[112]

Amiodarone has been studied in two major trials. The ARREST trial[115] was a randomized trial comparing amiodarone 300 mg to placebo in 504 patients. All patients were defibrillated three times, had CPR begun, were intubated and then given epinephrine 1 mg. They were then given amiodarone or placebo and defibrillated. After defibrillation the patients were treated with standard anti-arrhythmic therapy. The study showed that amiodarone had a significantly higher ROSC. The study was not powered to evaluate survival. The only other difference was amiodarone caused more bradycardia requiring atropine (41% versus 25%). The ALIVE trial[116] was a randomized comparison of lidocaine versus amiodarone. All patients were defibrillated, given epinephrine, and defibrillated again. They were then randomized to 1.5 mg/kg of lidocaine plus placebo versus 5 mg/kg amiodarone plus placebo. After another defibrillation they were given repeat doses of 1.5 mg/kg lidocaine plus placebo or amiodarone 2.5 mg/kg amiodarone plus placebo and defibrillated again. The group receiving amiodarone had a significant two-fold increase in initial survival. As the study had 340 patients, it was not powered to evaluate survival. Thus, amiodarone is an acceptable anti-arrhythmic agent during ventricular fibrillation.

The problem with anti-arrhythmic therapy is that there is no comparison to placebo, only comparisons to lidocaine. We do not know if lidocaine is beneficial as believed, or whether it has no effect or is harmful. As we do not truly know what the baseline is, we do not know if amiodarone is beneficial or not, even though it is superior to lidocaine in ROSC. There is a need for a true randomized survival trial with anti-arrhythmic therapy.

Hypothesis

In my view there are three different ways in which a victim has a cardiac arrest independent of rhythm. Each of these ways might end in ventricular fibrillation, asystole or PEA.

Primary arrhythmia: The most common method is a primary arrhythmia. The patient is normally perfused and has a sudden arrhythmia, most commonly ventricular fibrillation. This instantly stops circulation. The arterial blood is still oxygenated and oxygen is trapped in the lung. With agonal breathing in the context of no blood flow, it is possible that in the lungs the pCO_2 might fall and the pO_2 might rise or remain the same. In the myocardium, the cells have some substrate available for a short period of time. The cells probably leak hydrogen and potassium to the ECF. As the substrate is used up, the cells undergo progressive oxidative stress.

In this scenario for the first few minutes – maybe as long as 5 to 6 minutes – depending on the rhythm, either defibrillation alone or stimulation (for aystole or PEA) may be of benefit. CPR during this early phase may extend the window in which the victim can be resuscitated. Chest compression without ventilation is probably of benefit in this early stage. After this initial period – 5 to 8 minutes – the buildup of extra-cellular potassium and hydrogen may require some coronary blood flow prior to ROSC to lower the concentration. To achieve this coronary blood flow, CPR and a vasoconstrictor may be needed. After prolonged cardiac arrest, there may need to be higher flow to allow myocardial cells to overcome some of the insult. In this phase the combination of vasopressin and epinephrine and/or active compression-decompression CPR (ACD) may be needed to provide a higher coronary blood flow.

Hypoxia/shock: Another mechanism is for the patient to become hypoxic or be in profound shock. In this scenario, the cells may have little substrate left and are in a state of stress prior to the heart stopping. The arterial blood is probably hypoxic and acidotic. This group may only respond to methods that provide a higher coronary blood flow. This group is the one described that responded best to ACD and to the combination of vasopressin and epinephrine.

Sudden respiratory arrest: Drowning, anesthetics, paralytics, and others can cause a sudden cessation of breathing in an individual who was normally perfused. The heart continues to pump the oxygenated blood and continues to have gas exchange in the lung. The oxygen level in the blood slowly falls and the myocardial cells then become stressed. This group in the early phase responds to CPR and ventilation. Late this group progressively becomes similar to the hypoxia/shock scenario.

This hypothesis could explain the many different animal and human studies, but whether it is true or not will require a great deal more knowledge into the processes of cardiac arrest.

Summary

There have been some advances in resuscitation from cardiac arrest during the last nine years. The greatest changes are in the form of early defibrillation both with AEDs and ICDs. Both of these technologies have had a dramatic impact on survival. The expansion of their roles will increase the number of victims resuscitated, but they have a marked limitation. This technology can only be applied to a small percentage of the cardiac arrests. The problem is that many of the events are not witnessed. The other advances, though interesting, have only had a small impact on the overall survival. It should be noted that for the time being, the treatment that will have the greatest impact is prevention. The use of risk factor reduction, statin therapy, aspirin, beta-blocking agents, ACE inhibitors will have a far greater impact on the death rate than will attempts at resuscitation. There is a need for meaningful research so that more victims can be resuscitated. This is a challenge for all of the medical profession.

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