EARLY DEFIBRILLATION IN THE HOSPITAL: WE'RE NOT THERE YET!

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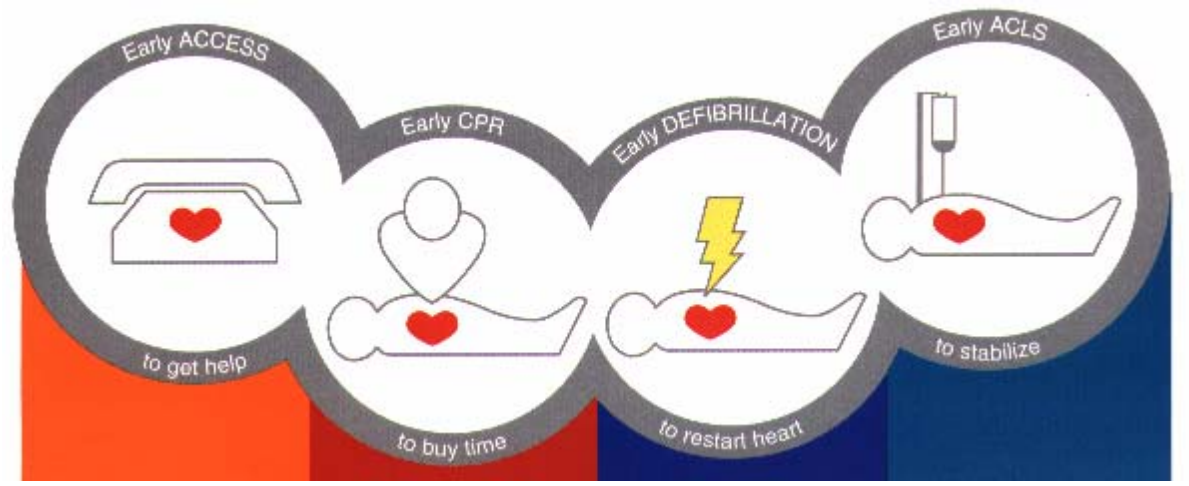
Introduction

Over 15 years ago the American Heart Association (AHA) introduced the concept of the chain of survival in cardiac arrests. There are four time-sensitive links which must occur rapidly for the victim to have a chance at survival:

- Early recognition of the emergency and activation of the local emergency response system
- Early bystander CPR
- Early delivery of a shock with a defibrillator
- Early advanced life support followed by post resuscitation care



Research has shown that the first three links are directly related to patient survival. More patients in the hospital on general care units are being monitored so that deteriorating hemodynamic and respiratory status along with lethal rhythms can be quickly identified. Hospitals have set up sophisticated systems for calling the CPR team. Most staff are required to be current in Basic Life Support (BLS) skills. Manual defibrillators are available in all critical care units, and ready to use once the CPR team arrives to general care units.

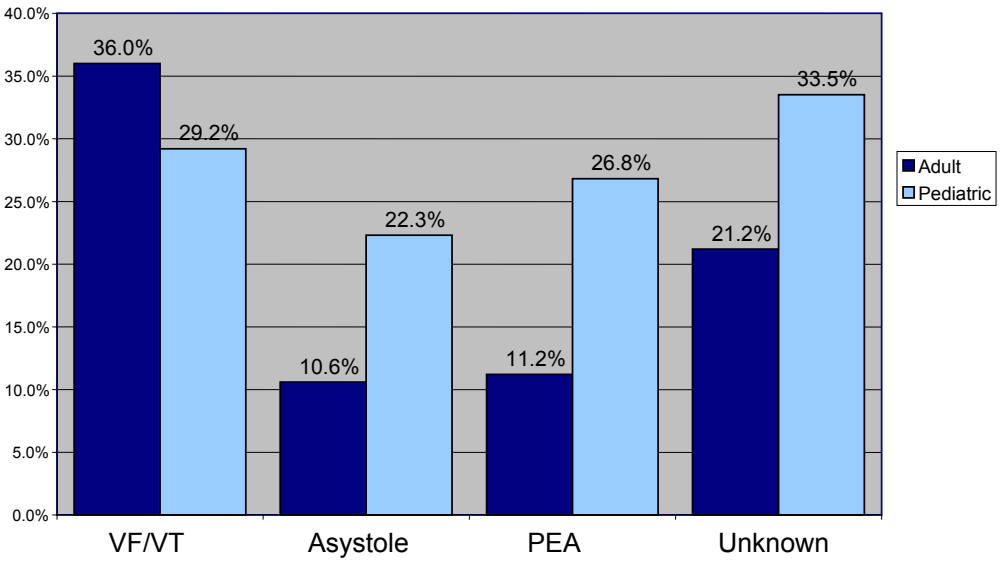
The AHA has given a Class I recommendation to immediate defibrillation as the treatment of choice for ventricular fibrillation (VF) of short duration as seen in witnessed sudden cardiac arrest. A Class I recommendation is one in which the benefit clearly outweighs the risk, and the "procedure/treatment or diagnostic test/assessment *should be* performed/administered." The AHA goal for early defibrillation in the hospital and ambulatory clinics is for the shock to be delivered within 3 minutes of the victim's collapse.[1]

Do you know the time to defibrillation within your institution for the critical care units, and more importantly the general care units, hallways where patients are transported and ambulatory care clinics? Have you instituted a system whereby first responders in all areas can perform the first *three* links in the chain of survival while they are waiting for the CPR team to arrive? With the availability of automated external defibrillators (AEDs), staff who are not trained to read ECG rhythms can quickly and competently deliver a shock to those patients in cardiac arrest who have VF. Some hospitals have moved to a two-tiered defibrillator system, with manual defibrillators in the critical care units and AEDs in the other areas.

What Have We Learned from the NRCPR?

The National Registry of CardioPulmonary Resuscitation (NRCPR®) is an international database of in-hospital resuscitation events sponsored by the American Heart Association. Initiated in 2000, the NRCPR now contains over 75,000 resuscitation events from over 370 participating hospitals in the US, Canada, Germany, Japan, and Brazil. In their latest publication by Nadkarni et al describing events through March, 2004, outcomes of in-hospital pulseless cardiac arrests for adults and children are presented by first documented pulseless arrest rhythm.[2] See figure 1.

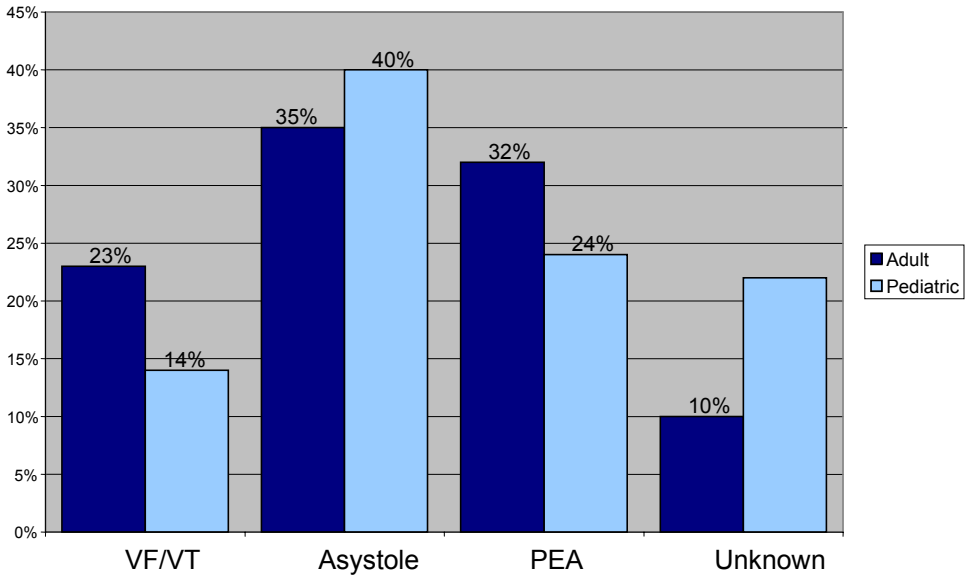
Figure 1. Survival to discharge by first documented pulseless rhythm from NRCPR data through 3/04



The combined discharge rates are disappointing: 18% in adults and 27% in children. What is even more dismal is that the hospital discharge rate following resuscitation hasn't changed in 40 years. Note that the discharge rate for VF is more than triple that for asystole or pulseless electrical activity (PEA). Thus, improvements in resuscitation practice for adult patients would have their greatest impact in those who have VF as the initial rhythm.

How often is a shockable rhythm noted as the initial rhythm in an in-hospital cardiopulmonary arrest? Again, NRCPR can supply meaningful information from the same report. See figure 2.

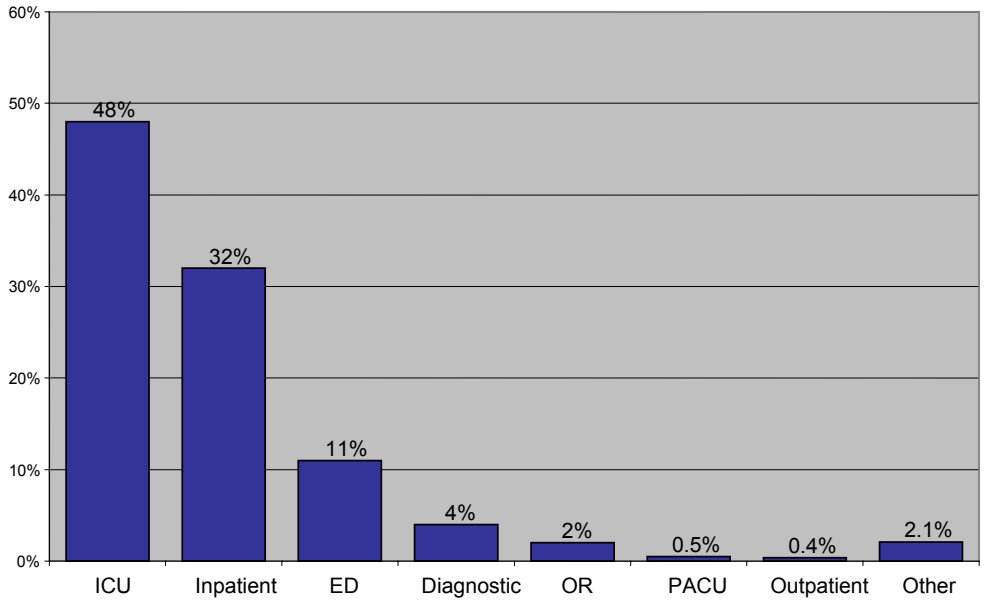
Figure 2. Prevalence of first documented pulseless rhythm from NRCPR data through 3/04



Most in-hospital cardiac arrests in both adults and children were not sudden shockable cardiac arrhythmias, VF or pulseless ventricular tachycardia (VT). Instead most of these arrests were associated with progressive respiratory failure, circulatory shock, or both.

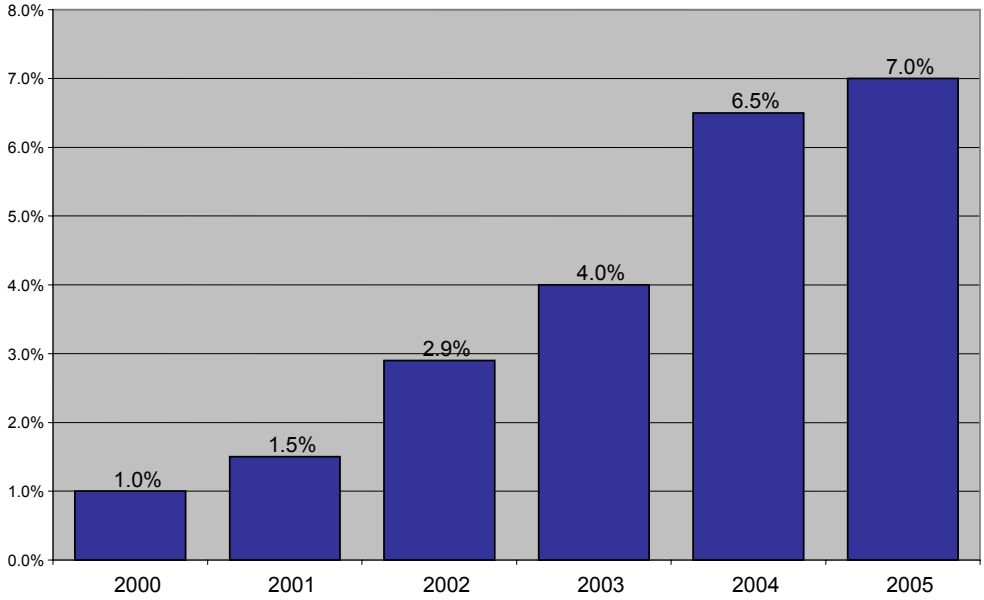
From the first published article describing NRCPR data through June 2002 by Peberdy et al,[3] the event location of the first resuscitation event for patients is shown in figure 3.

Figure 3. Cardiopulmonary resuscitation initial event location from NRCPR data through 6/02



It was reported at the NRCPR Users Group conference in 2005 that the use of AEDs in hospitals has been slowly increasing. The rate of the first defibrillation shock being delivered to adults by an AED has increased in their database from 1.0% in 2000 to 8.8% in 2006.[4] See figure 4.

Figure 4. First shock delivered by AED from NRCPR data through 7/05

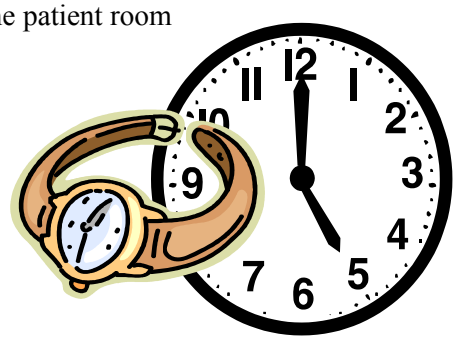


Time Interval and Defibrillation Success

Since the AHA Guidelines 2000 we have been taught that for every minute that passes between collapse and defibrillation, survival rates from witnessed VF sudden cardiac arrest decrease 7 to 10%. When bystander CPR is provided, the decrease in survival rates is more gradual and averages 3 to 4 % per minute.[1]

If the goal of defibrillation in the hospital is within three minutes, does your institution know when this time interval has been accomplished for individual resuscitation events? It is difficult to obtain accurate time intervals for resuscitations because most hospitals do not document their time of collapse, time of notification of the CPR team, and time of defibrillation using *one* clock. I wrote about this problem in a previous issue of *CodeCommunications*.

Kaye reports[5] that when nurses at an urban academic medical center were asked what timepiece they used for documenting times during codes, 31.3% reported using only patient room clocks, 44.8% reported using only their watches, and 23.9% reported using one of several sources including patient room clocks, their watches, the defibrillator clocks and the emergency timers in patient rooms. Additionally, the precision of the timepieces used was inaccurate. The watches used by the nurses varied from atomic time by a mean of 2.4 minutes, the defibrillator clocks by 4.58 minutes, and the patient room clocks by 3.11 minutes.

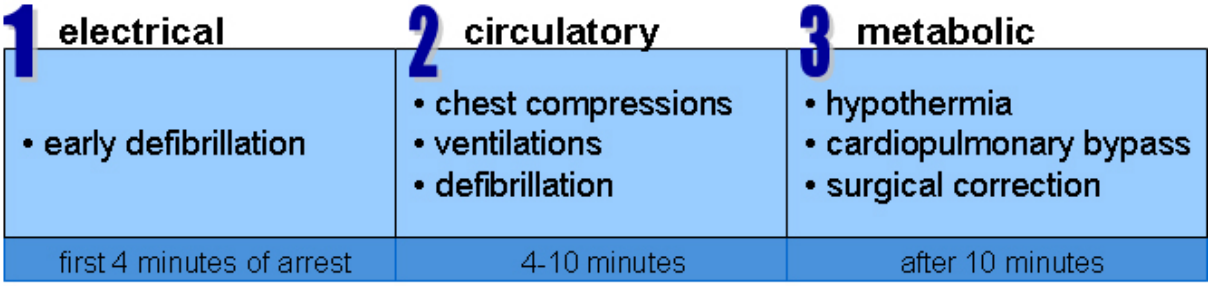


ZOLL CodeNet electronic documentation system for resuscitations provides the means to synchronize times from the defibrillator with event documentation on a pocket PC during the code. This can be synchronized then with time on the institutional network computers. Operator time for calling the CPR team can be manually set to network time – so now all clocks are on the same time and time intervals can be accurately calculated.

Prior to instituting an in-hospital BLS-AED program, a 2-year review of unmonitored arrests by Kaye documented a delay of more than 5 minutes between recognition of the arrest and the first defibrillation countershock.[6] If you are to implement an early defibrillation program within your hospital, you will need to first determine the time of collapse to defibrillation for those patients in a shockable rhythm. In my practice at Dartmouth-Hitchcock Medical Center (DHMC) we used the time of the call to Communications, who then paged the CPR team, as the surrogate for the time of collapse. Measure how long it takes the operator to put out the page to the CPR team from the time of the call. At DHMC this time interval was around 40 seconds. I have heard some institutions state that it takes over one minute for an emergency page to be broadcast through their computer system. If the CPR team was not called, e.g. in a critical care unit or the OR, we often used the time CodeNet was turned on for estimating time of collapse. Some institutions require that all documentation be timed using one clock, e.g. the wall clock in the patient's room.

3-Phase Time Sensitive Model of Resuscitation

Weisfeldt proposes a 3-phase model of CPR for patients in VF or pulseless VT to reflect the time-sensitive progression of resuscitation physiology, which in turn requires time-critical interventions.[7] The first phase, the *electrical phase*, extends from the time of arrest to approximately 4 minutes following the arrest. The most effective intervention during this phase is defibrillation. An example of the efficacy of defibrillation during the electrical phase is the success of the implantable cardioverter defibrillator (ICD), which provides defibrillation within 15 to 20 seconds of the onset of VF and rarely fails to restore organized electrical activity. The practice of early defibrillation within this electrical phase in out-of-hospital and in-hospital environments results in survival rates approaching 50%.



3-Phase Time Sensitive Model of Resuscitation

The *circulatory phase* of VF lasts from approximately 4 to 10 minutes of arrest. The most lifesaving therapy during this phase is to initiate a technique to first provide oxygen delivery, i.e. chest compressions and ventilations (CPR), followed by defibrillation. Neimann et al reported that after 7.5 minutes of untreated VF in animals, 5 minutes of CPR plus epinephrine resulted in a significant improvement in survival compared with immediate defibrillation (64% vs 21% survival).[8] In contrast, after a shorter 5-minute period of untreated VF, use of CPR first failed to provide any benefit over immediate defibrillation.[9] Several clinical studies suggest that the same survival effect may hold true in humans.[10, 11] It is thought that limited circulation of blood with CPR partially restores substrates including oxygen and washes out deleterious metabolic factors that have accumulated during ischemia. Once the heart is "primed" it can respond to defibrillation with restoration of a cardiac rhythm and effective pumping.

After approximately 10 minutes of cardiac arrest, in the *metabolic* phase, the effectiveness of both immediate defibrillation and CPR followed by defibrillation decreases rapidly and survival rates are poor. Tissue injury from global ischemia and from reperfusion can result in circulating metabolic factors that cause additional injury to the whole body. Interventions that may be of use during the metabolic phase include the use of hypothermia, cardiopulmonary bypass, and surgical correction of the underlying cardiac pathology.

The research and development challenge is to produce a reliable device or method for determining the time elapsed since collapse, especially for unwitnessed arrests. Then further studies can be set up targeting interventions to the specific phase and determining their impact on survival.

Survival with Early Defibrillation Out-of-Hospital

It has clearly been demonstrated that reducing the time to defibrillation in out-of-hospital cardiac arrests improves survival to hospital discharge. Positive results have been reported with earlier defibrillation by EMTs, police, casino staff, airline employees, and the lay public. Emergency medical services (EMS) have instituted two tiers of response, using BLS-trained EMTs to perform defibrillation as the first level and paramedics to deliver ACLS at the second level. An early metaanalysis by Auble[12] of seven studies (only 3 studies with random assignment), concluded that defibrillation by EMT-BLS personnel who could perform defibrillation (two-tiered response system) significantly reduced the risk of mortality for victims in ventricular fibrillation compared with systems in which only BLS was delivered by the initial team and defibrillation delivered later when the paramedics arrived (one-tiered system). The reduction in the risk of mortality was approximately 8.5% with the addition of defibrillation to early BLS care. Manual, semiautomatic, and automatic external defibrillation devices were used in this study.

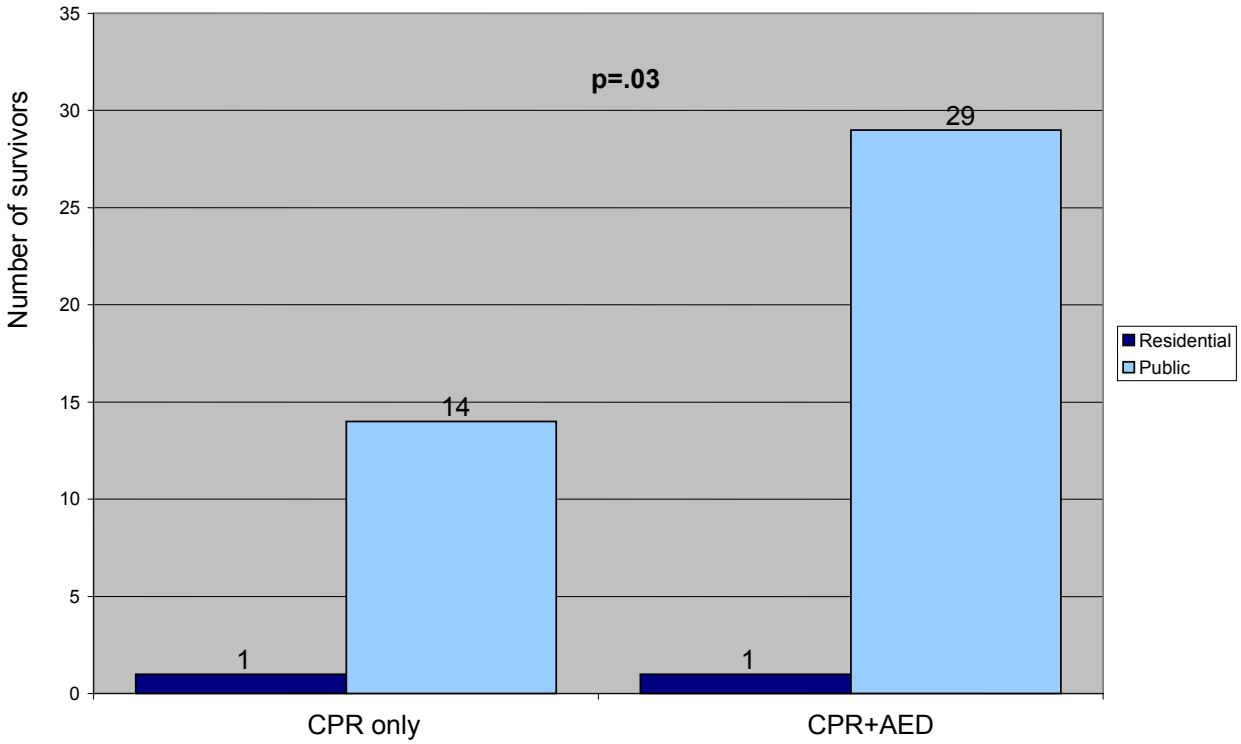
Even though Ontario had an ambulance-based BLS-D EMS system, their published overall survival rate was low at 2.5%, associated with a mean response interval to defibrillation of 13.1 minutes. The Ontario Prehospital Advanced Life Support (OPALS) study was funded, with one of the purposes defined as a defibrillator arriving at the scene within 8 minutes. Multiple changes were made to their EMS system to facilitate earlier defibrillation, one of which was authorizing police to use an AED. Improvement was demonstrated in return of spontaneous circulation (by 25%), admission to the hospital (by 34%), and

survival to hospital discharge (by 33%). Both response with a defibrillator within 8 minutes and CPR initiated by bystanders or first responders was associated with significantly improved survival.[13]

Valenzuela reported amazing results in 2000 with AED use in U.S. casinos by security officers, resulting in a 53% survival to discharge from the hospital.[14] Among the 90 patients whose collapse was witnessed, the clinically relevant time intervals were a mean of 3.5 ±2.9 minutes from collapse to attachment of the defibrillator, 4.4 ±2.9 minutes from collapse to the delivery of the first defibrillation shock, and 9.8 ±4.3 minutes from collapse to the arrival of the paramedics.

The recent widely-publicized Public Access Defibrillation (PAD) trial was a prospective, randomized community-based study in North American that compared the number of out-of-hospital cardiac arrest victims who survived to hospital discharge between public settings (mostly recreational facilities and shopping centers) with trained responders who could recognize the event, call 911, and perform CPR versus public settings that also provided defibrillation using AEDs. 993 carefully selected community units composed of 1260 settings were randomized for this trial, and 19376 lay responders were trained. The number of patients surviving to hospital discharge was significantly greater in the CPR+AED group (30 vs 15, p = .03) compared with the CPR-only group.[15] See figure 5. The actual effect of widespread implementation of lay public AED programs on survival after out-of-hospital cardiac arrest in community locations is likely to be moderate overall, since the majority of out-of-hospital arrests occur in the home.

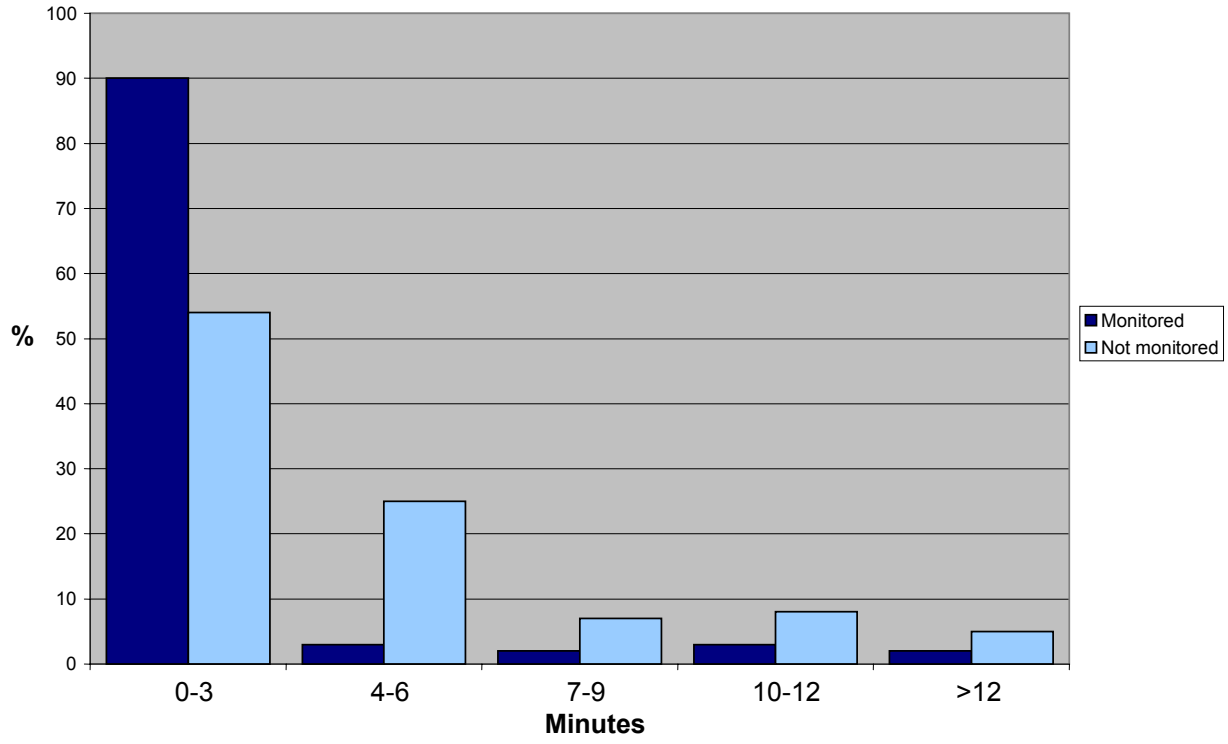
Figure 5. Comparison of survival in CPR only vs CPR+AED arms of PAD trial



Survival with Early Defibrillation in the Hospital

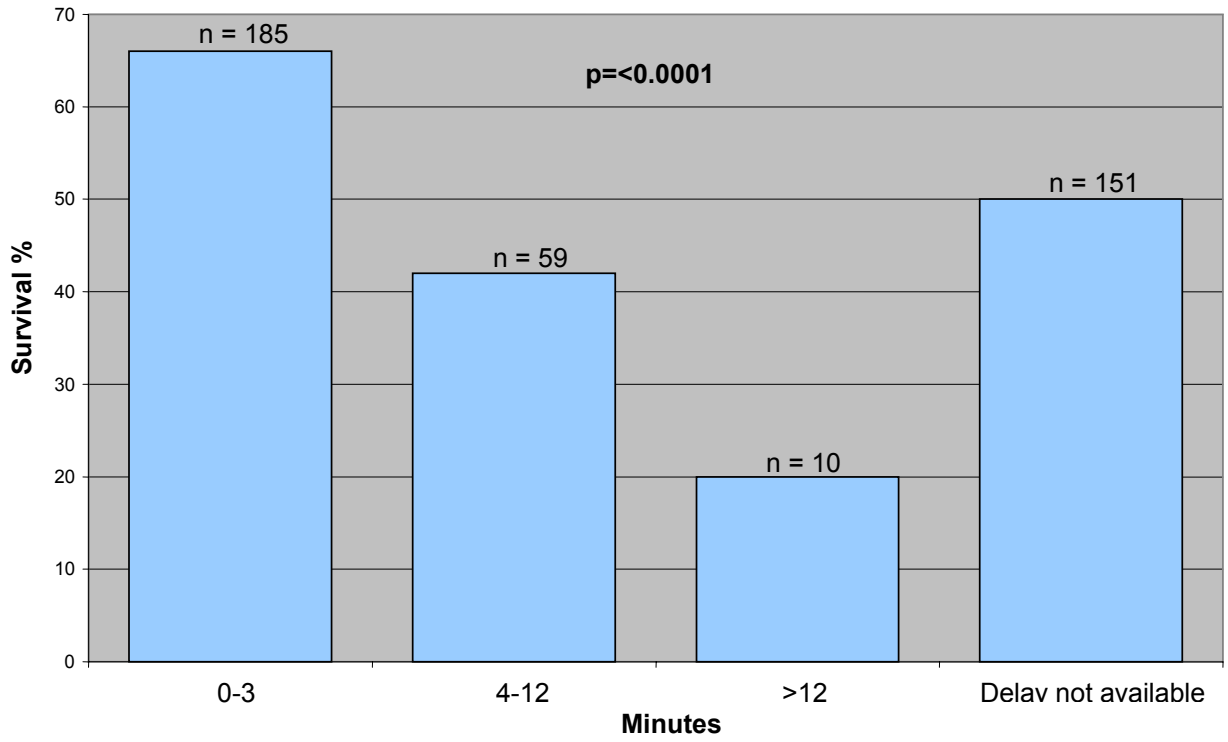
There is a small body of literature that looks at survival of in-hospital patients in monitored vs non monitored units, and how this relates to time to defibrillation. Herlitz studied all patients who suffered an in-hospital cardiac arrest for whom the rescue team was called from 1995 until 2002 in Sahlgrenska Hospital, Goteborg, Sweden.[16] For the total study period survival to discharge was 58% for patients found in VF, 24% for asystole, and 9% for PEA. On the monitored wards, 59% of the patients were found in VF/VT vs 45% on the non-monitored wards (p = <0.0001). The most likely explanation of this finding is that the ECG recording took place much earlier in the course among patients suffering a cardiac arrest on wards with monitoring facilities. The overall survival to discharge for those in VF was 60% in monitored wards vs 57% in non-monitored wards (NS). Note in figure 6 that 90% of the patients were defibrillated ≤3 minutes after collapse on monitored wards vs 54% on non-monitored wards (p = <0.0001).

Figure 6. Percentage of patients defibrillated within various intervals after collapse



There was a strong relationship between the time from collapse until the first defibrillation and survival among all patients (p = <0.0001). See figure 7. If defibrillation occurred ≤3 minutes after collapse, 66% survived to discharge, as compared to 20% if defibrillation took place > 12 minutes after collapse. Patients defibrillated at an early stage among the non-monitored patients had a similar survival rate as the corresponding group in monitored areas.

Figure 7. Survival related to interval between collapse and first defibrillation



Many institutions have a one-tiered defibrillation system in which defibrillation is delivered once the CPR or ACLS team arrive. The CPR team brings a manual defibrillator with them, or manual defibrillators are placed around the institution so that one can be brought to the scene for use by the advance team. This approach lends itself to delayed defibrillation, with the longer time to defibrillation negatively impacting survival. Some institutions have instituted a two-tiered system, whereby manual defibrillators with monitoring, cardioversion, defibrillation, and external pacing capability are placed in the critical care units and brought to the resuscitation site. AEDs are additionally placed on the general units where staff do not have ECG analysis skill to enable early defibrillation by first responders prior to CPR team arrival. Randomized studies to warrant a firm recommendation regarding early defibrillation with AEDs in the hospital setting were not found when the 2005 AHA Guidelines were published.

Kenward published in 2002 a review of primary research related to in-hospital use of AEDs and resuscitation outcome.[17] Sample size in the five studies that met his inclusion criteria were small, methodological issues were highlighted, and incomplete demographic data precluded metaanalysis. He identifies a need for higher quality prospective research and audit.

Single institutions have reported success stories with implementation of an AED program for first responders. The Atlanta Veterans Administration Hospital replaced all their manual monophasic defibrillators with a combination of biphasic manual and automated defibrillators. With the new defibrillators, survival of all patients with resuscitation events improved 2.6-fold, from 4.9% to 12.8%. The improvement in mortality was attributable solely to an effect on patients presenting with VF/VT; their survival improved 14-fold.[18] At Miriam Hospital in Providence, Rhode Island, Mancini and Kaye report that AED use over 2 ½ years in non-critical care areas doubled the survival-to-discharge rate (6/10

or 60%) when compared with conventional defibrillation by the ACLS CPR team (9/28 or 32%)[19] At a university hospital in Germany Hanefeld reports that 14 AEDs were installed so they could easily reached from the wards.[20] During their first year of experience an AED was applied and activated by nurses/medical staff before the cardiac arrest team arrived in 27 of 33 cases (81.8%) of witnessed cardiac arrest. The median time from onset of the emergency call to the activation of the AED averaged 2.1 minutes, whereas the median arrival time for the CPR team was 4.7 minutes. In 18 of 27 cases in which the AED was instituted promptly, the primary arrest rhythm was either VT or VF, and the AED delivered a shock. For this subgroup, the rate of return of spontaneous circulation and the rate of discharge to home were 88.9 and 55.6% respectively.

Mancini reported at the NRCPR Users Conference in 2006 that in their aggregate adult data if defibrillation was reported to be delivered within 3 minutes, the discharge rate was 79% compared to 21% when defibrillation took longer.[4]

Implementation of an AED Program in the Hospital

In spite of the lack of research on in-hospital use of AEDs, the benefits of early defibrillation are not disputed. If you have accurately measured your institution's time from collapse to defibrillation, you will reach the conclusion that defibrillation on the general wards where nurses are not authorized to defibrillate is delayed – until the CPR team arrives. The AHA recommends that "AEDs should be considered for the hospital setting as a way to facilitate early defibrillation, especially in areas where staff do not have rhythm recognition skills or defibrillators are used infrequently."[1]

To determine where AEDs would be placed at Dartmouth-Hitchcock Medical Center, I walked the halls with a stopwatch. We decided that an AED would be placed so that it took no longer than one minute to walk rapidly and retrieve an AED, one minute to return to the patient, and one minute to apply and use it. New biphasic AEDs were purchased for general inpatient units where staff did not have rhythm recognition skill, for outpatient clinics, diagnostic/treatment areas (e.g. radiology, endoscopy, dialysis, physical therapy, sleep clinic), long hallways where patients are transported, and public areas where outpatients/visitors are found. All staff who provided direct care to patients were already required to be current in Basic Life Support, which included AED training. We just adjusted the training and competency demonstration to be specific to the one standard AED that we purchased. The single message to the staff was that the AED works, is easy to use, and is safe. Manual defibrillators can have an integrated automatic advisory setting, but we decided to purchase a less expensive stand-alone "shock box" so the general unit staff would not be intimidated by the hardware. In the next issue of CodeCommunications, I'll discuss how to choose an AED. But several factors to consider when selecting an AED specific to the hospital setting include:

- Presence of ECG waveform on the AED screen
- Ability to perform manual override
- Need for feedback on performance of CPR

Nurses and physicians on the CPR team were trained in automated defibrillation so they would know how to interface with the AED. Since the ECG rhythm was difficult to see on the small AED screen, especially with it lying on the bed, the CPR team nurse would soon switch the patient from the AED to a manual defibrillator. The CPR team nurses needed reminding that they did not need to change out the defibrillation electrodes at this time. If the automated and manual defibrillators are by the same manufacturer, then the same electrodes will work with both devices. If the defibrillators are by different manufacturers, then a simple cable connect needs to be available. Some hospitals have not converted over to "hands-off" defibrillation electrodes. Implementation of AEDs is a good time to change over from paddles to pads on manual defibrillators also.

AEDs come with the capacity to download the data, so consider purchase of the data management program. Begin downloading data from both manual and automated defibrillators and place it into an electronic resuscitation management program that will help you collect and summarize pertinent data. Change your CPR record to include information about whether an AED was used, and if so whether shocks were advised and given. Our hospital policy was changed to authorize any care provider trained in defibrillation (whether manual or automatic) to use that skill when confronted with a victim in cardiac arrest anywhere within the institution – prior to the arrival of the CPR team.

Measures of success of an early defibrillation program with AEDs should include:

- Frequency of use of an AED for arrests outside the critical care units
- Initial rhythm when AED attached (downloaded from the AED later)
- Frequency of shocks delivered by first responder staff prior to arrival of CPR team
- Time to first defibrillation
- Patient survival to discharge for patients in VF/VT, separated out for manual and automated defibrillation

When I received CPR records from events occurring on units with an AED, I would always review the data to see if the AED was applied. Often I would talk with the first responders who used the AED to ask how it went and if they had any concerns. A first measure of success was whether the defibrillation electrodes were in place upon arrival of the CPR team so they could immediately determine the patient's rhythm. If shocks were delivered by the first responders I would congratulate them and give them a print-out of the ECG containing the shock. In my written audit of the resuscitation sent to the nursing leader of the unit, I would point out that their staff had incorporated this new technology into practice. When a patient survived to discharge who had been initially shocked by first responders using an AED, I would write a letter of commendation to them and give a reward, e.g. dinner at a local restaurant.

Change in Roles with an In-hospital AED Program

I believe that the survival of a patient in cardiac arrest, especially those in VF/VT, is more often related to the actions of the first responder than to those of the ACLS team. When a patient arrests on a general care unit, there are usually several staff members immediately available. The first responder should assess the adult patient, call for help, get the patient into a position to perform CPR, and start CPR. The second responder should make sure that the CPR team is notified and bring the AED, apply it and use it. Research has shown that survival is not improved whether CPR is administered or not during the first few minutes following collapse of a victim in VF/VT, but most inpatients are not in VF/VT – so CPR should also be emphasized. When defibrillation is delayed CPR prolongs the time VF is present and increases the likelihood that a shock will terminate VF and allow the heart to resume an effective rhythm with adequate perfusion.

How CPR is interfaced with defibrillation should be taught to providers and actually practiced, so that interruptions in compressions and "no flow time" are minimized. Compressions should be continued for two minutes after defibrillation until effective perfusion returns. In the rare circumstance that only one trained provider is initially present, then a closeby AED should be retrieved and applied instead of performing CPR. First responders can perform 3 of the 4 links in the chain of survival.

Patients who have PEA and/or asystole as the initial rhythm in cardiopulmonary arrest often have premonitory signs. With the advent of rapid response teams, nurses on general units may have a team to call for help when a patient demonstrates selected criteria so that cardiopulmonary arrest can be prevented. These nurses can receive additional education on how to recognize and support unstable patients.

Peters and Boyde report that with implementation of an AED program at Princess Alexandra Hospital, 100% of the trained staff reported feeling they were pro active, in control and capable.[21] 75% of the nurses felt empowered and confident. The CCU nurses reported that the ward staff were more directly involved in resuscitations. It was felt that there is a definite relationship between the AED training and attitudes, and that consideration must also be given to the human and cultural elements when applying new evidence to practice.

The role of the CPR team can be modified. Their primary role should be to care and plan the further management of those patients who have achieved first responder return of spontaneous circulation. A secondary role is to continue resuscitation in those patients in whom first responder initial resuscitation efforts have failed. These efforts are often futile. Decisions concerning when to stop resuscitation or whether to make further resuscitation attempts remain the responsibility of the CPR team.[22]

Conclusion

The initial rhythm for patients who arrest in the hospital which yields hope of survival is ventricular fibrillation and/or pulseless ventricular tachycardia. The most important link in the chain of survival for those in VF/VT is defibrillation. The earlier that defibrillation is delivered, the greater chance of survival. In most institutions defibrillation is delivered on general care units once the CPR team arrives, which is often at least 5 minutes after patient collapse. AEDs are easy and safe to operate, and cost effective. Nurses on general care units, trained to use an AED, can make the difference in whether a patient in VF/VT lives or dies. Isn't it time that your institution consider a two-tiered defibrillation system incorporating use of AEDs? Begin by measuring the time from collapse to defibrillation. Then place AEDs in those areas with the longest response times. Finally, walk the floor plan and place AEDs strategically to assure that defibrillation is delivered within 3 minutes anywhere within your institution.

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