IT'S ALL ABOUT COMPRESSIONS— *AND DEFIBRILLATION*!

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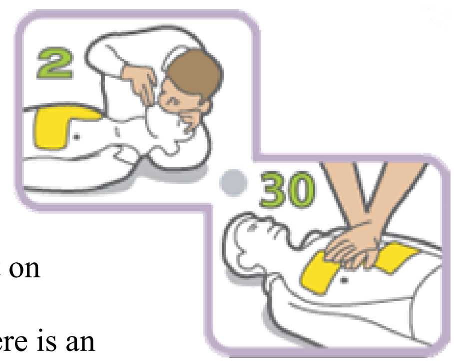
When you read the *2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care*, it quickly becomes evident that the major emphasis is on early, high-quality CPR for victims of cardiac arrest. Quality CPR and early defibrillation are inextricably linked. The combination is essential to increasing the survival rate for victims of sudden cardiac arrest. The emphasis in this article is on effective CPR in the hospital environment.

Key Elements of Effective Compressions

The American Heart Association provides the following guidelines for effective compressions in the healthcare environment:[1]

- Push hard and push fast. Compressions should be delivered at a rate of 100/minute (except in the newborn) and a depth of 1.5-2 inches (adults only).
- Allow the chest to recoil completely after each compression so that the heart can refill.
- Equalize the compression and relaxation phase time.
- Minimize interruptions in compressions. No more than 10 seconds should elapse for pulse/rhythm checks and for ventilations prior to the insertion of an invasive airway. Perform defibrillation and intubation as quickly as possible.
- Utilize the ratio of 30 compressions to 2 ventilations for one-rescuer CPR in victims of all ages (except newborns) and 2-rescuer CPR of adults prior to the insertion of an invasive airway.
- Rotate the compressor every 2 minutes to avoid the fatigue effect on compression quality.
- After a shock palpate for a pulse following 5 cycles of CPR if there is an organized rhythm.



Key Elements of Effective Ventilations

In addition to effective compressions, ventilations should be performed according to the following recommendations:

- For best outcome provide both ventilations and compressions for a cardiopulmonary arrest.
- Deliver each breath over one second so that the chest rises.
- Do not hyperventilate the victim. Once the invasive airway is in place, deliver 8-10 breaths/minute without interrupting compressions (adults).

The Rhythms of Cardiopulmonary Arrest

During the recent past, emphasis has been placed on early defibrillation in order to save more lives. Many persons think that ventricular fibrillation (VF) and pulseless ventricular tachycardia (VT) are the most frequent initial rhythms in cardiopulmonary arrest of adults. In children it is thought that these shockable rhythms are rare since their arrests are most often due to respiratory failure, circulatory shock, or both.

Nadkarni et al, in their publication *First Documented Rhythm and Clinical Outcome from In-Hospital Cardiac Arrest Among Children and Adults*, report on data from the National Registry of CPR (NRCPR) between January 1, 2000, and March 30, 2004.[2] The prevalence of first documented rhythm in arrest can be found in figure 1. It is surprising to note that VF/pulseless VT occur as the initial rhythm in only 23% of adult victims in the hospital, yet is seen in 14% of the pediatric population. Survival to discharge was 18% in the adult population and 27% in children. The improved outcome in children compared to adults (24% vs. 11%) was found primarily in those with pulseless electrical activity (PEA) and asystole.

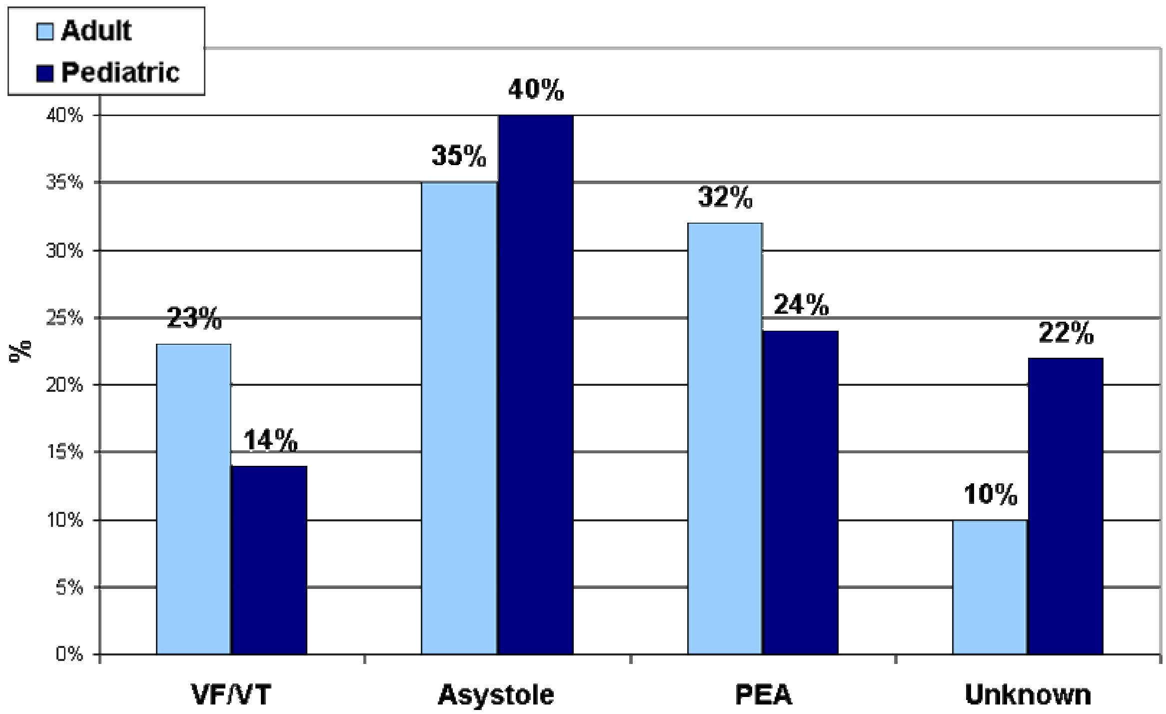


Figure 1 - Prevalence of first documented pulseless rhythm from NRCPR data

VF is usually a manifestation of severe, undiagnosed coronary artery disease (CAD). Deaths from CAD peaked in the 1960s and declined by over 50% in the late 1990s. It is thought that this decrease is due to:

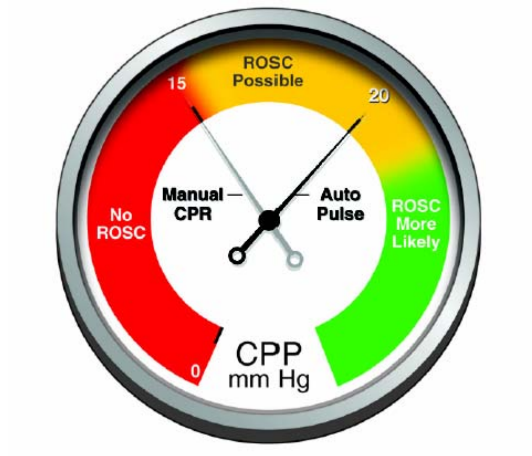
- Primary and secondary prevention
- Early diagnosis
- Aggressive successful treatment
- Decline in undiagnosed CAD

PEA is a common stage in clinical death from any variety of tissue hypoxia/anoxia insults. Animal studies from four research groups delineate the resultant dying process:

> *"The conscious animal attempts to compensate by an increase in ventilatory rate and depth. In animal models, blood pressure rises rapidly and often dramatically. As compensation fails, the level of consciousness declines first, followed rapidly by hypoventilation, hypotension, bradycardia, and then respiratory and cardiovascular collapse. The blood pressure drops during crisis to undetectable levels during a period of 15-30 seconds. The ECG continues with bradycardic rhythms of a wide range of sources, which in the face of undetectable pulse constitute PEA, for seconds to minutes until it decays to asystole."*[3]

Physiology of Effective Compressions and Ventilations

With the occurrence of VF, blood pools in the right heart causing distension. Over three minutes, the left heart empties. When the blood pressure on the arterial side equals that on the venous side after about five minutes, carotid blood flow and coronary perfusion pressure (CPP) fall to zero. CPR shifts blood from the distended right side to the left side and blood flows out of the heart through two mechanisms: 1) changes in intrathoracic pressure and 2) direct compression of the heart. It takes about 1.5 minutes of CPR to get the CPP up to an adequate level so that cardiac function may return. Paradis found in his study that no patient experienced return of spontaneous circulation (ROSC) unless CPP was greater than 15 mm Hg.[4] CPP is defined as the difference between aortic pressure and right atrial pressure.



CPP Gauge

When VF is present for more than a few minutes, the myocardium is depleted of oxygen and metabolic substrates. CPR is needed to decrease the myocardial dysfunction so that electrical shock can restore a pulse.

The focus in PEA and asystole is to perform high quality CPR with minimal interruptions and to identify reversible causes or complicating factors.

Higher compression rates are associated with improved ROSC. Abella, in his prospective observational study of cardiac arrests in three hospitals found that there is a threshold effect, with survival diminishing when the rate drops to somewhere between 80 and 90/min.[5]

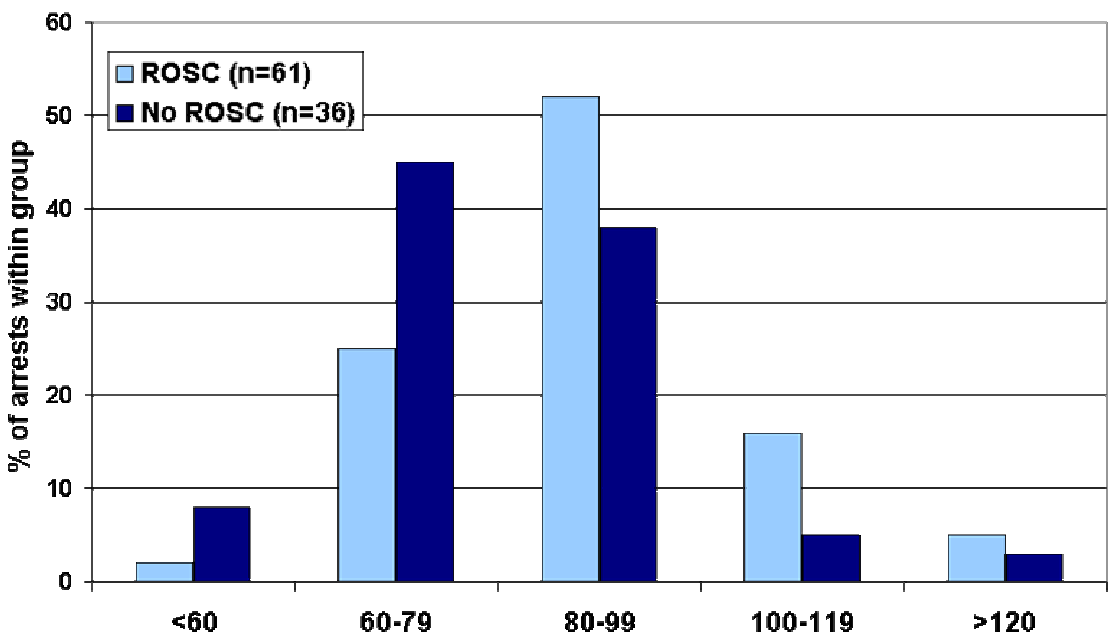


Figure 2 - Chest compression rates correlate with return of spontaneous circulation (ROSC)

Yannopoulos showed in the pig model that incomplete decompression during the performance of CPR increases the frequency and duration of positive intrathoracic pressure, inhibiting venous blood return to the right heart (preload) and decreases systolic, diastolic, and mean arterial pressures, consequently reducing CPP.[6]

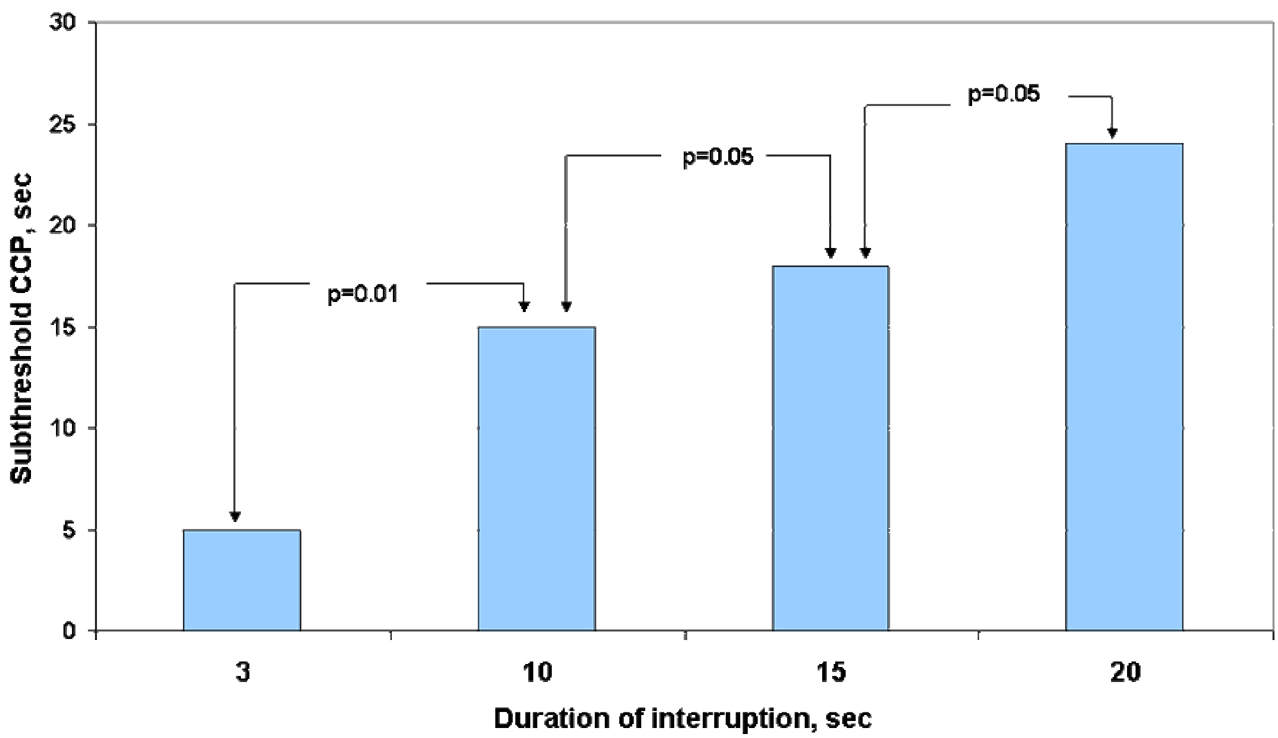
CPP, hemodynamic function and survival are adversely affected by even short pauses in compressions. The impact of pauses from 3 to 20 seconds on CPP during the initial 3 minutes of CPR are shown in the figure 3 representing Yu's research.[7]

During CPR, blood flow to the lungs is substantially reduced, so an adequate ventilation-perfusion ratio can be maintained with lower tidal volumes and respiratory rates than normal. Too many breaths or too large a volume blunt the development of negative intrathoracic pressure, decreasing venous return to the heart, cardiac output, CPP, and survival.

Ashton studied the effect of rescuer fatigue on compressions performed on a Laerdal Skillmeter Resusci-Anne manikin by nurses and doctors in the UK. He found that the number of satisfactory compressions declined progressively over three minutes, and that the subjects did not even recognize deterioration in their technique.[8]

If defibrillation is effective in restoring a coordinated rhythm, PEA or asystole are usually present for a few minutes until blood is restored to the left ventricle. Thus, the AHA now recommends performing CPR for 5 cycles after a shock without first checking for a pulse. Then check a pulse after about two minutes of CPR if there is an organized ECG rhythm. CPR will provide oxygen and the metabolic substrates necessary for heart function to return, along with the necessary blood volume.

Figure 3 - Relationship between duration of interruption in compressions and coronary perfusion pressure



Is Our CPR Really that Bad?

The resuscitation world took notice when Abella published in JAMA his research *Quality of Cardiopulmonary Resuscitation During In-Hospital Cardiac Arrest*.[9] Given the paucity of data on actual performance, he sought to determine whether well-trained hospital staff perform CPR compressions and ventilations according to guideline recommendations. An investigational monitor/defibrillator was used which had the capabilities for capturing and recording rate and depth of chest compressions, rate and volume of ventilations, presence or absence of a pulse, as well as standard ECG and defibrillator shock event data. No-flow time was calculated as time periods during cardiac arrest without compressions being performed. The first 5 minutes of CPR was divided into 30-second segments and analyzed for 67 patients at the University of Chicago Hospitals. His findings include:

- Mean chest compression rate was < 90/min 28.1% of the time, and < 80/minute 12.8% of the time.
- Chest compressions were too shallow (< 38 mm or 1.5") 37.4% of the time.
- Ventilation rates were too high; during 60.9% of the 30-second segments ventilations were performed at a rate of > 20/min.
- The no flow fraction (NFF) yielded a mean of 0.24 with 40.3% of the segments having a NFF of > 0.20. (Note: a 10-second pulse check every minute of CPR would yield an NFF of 0.17.)

The study was not powered to relate CPR performance to patient outcome. These data suggest that CPR quality is highly variable in hospital practice.

Return of spontaneous circulation (ROSC) is associated with a CPP > 15 mm Hg. A study by Timerman et al demonstrated that manual chest compressions, even when delivered by experienced well-trained providers, were unlikely to consistently exceed a CPP of 15 mm Hg.[10]

There are inherent pauses associated with the use of automated external defibrillators (AEDs). Berg found with 64 out-of-hospital VF arrests that the median interval from turning on the AED power to the first shock delivery was 46 seconds by EMS. The median interval from the first shock to the first compression was 38 seconds.[11] He speculates that similar delays associated with AED use, before or after defibrillation, may partially explain why outcomes do not necessarily improve with the availability of an AED. Von Alem studied police and firemen during 184 arrests out of hospital in which they used AEDs for a median time of 4 minutes 47 seconds. He found that 40% of the potential time available for compressions during resuscitation of patients with a shockable rhythm was lost due to AED prompts, and another 23% was lost due to human factors (e.g. landmark identification, time for pulse check). Thus compressions occurred on average for only 37% of the time that resuscitation was being attempted.[12]

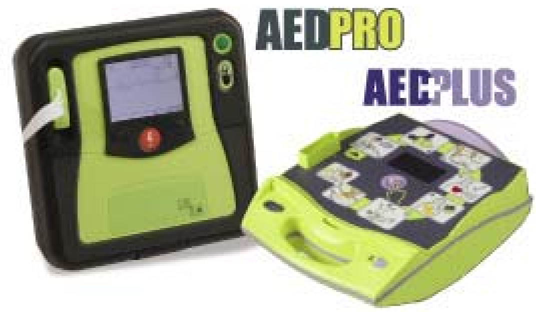
In Milwaukee Aufderheide observed EMS personnel performing CPR with seven consecutive patients in the field. The average maximum ventilation rate was 37 +/- 4 breaths/minute. After retraining in the classroom, half of the group still had ventilation rates ≥ 26 breaths/minute.[13]

Heidenreich believes that "two quick breaths" is an oxymoron. The AHA recommends that the single rescuer deliver 2 ventilations over 4-5 seconds. He found that in medical students after an initial Basic Life Support training course, it took them 14 +/- 1 second to deliver the two breaths during CPR on recording Resusci Anne manikins. Six months later the two breaths were delivered over 12 +/- seconds, but with significantly less minute ventilation.[14]

What Other Measures May Improve Success with CPR?

Feedback Devices

Feedback mechanisms to ensure proper compression rate and depth could help maintain CPP. A simple device, such as a musical metronome, could be used during training and even during actual arrests to assure a rate of 100/minute. All the major defibrillator manufacturers are working on some type of feedback in their devices. The ZOLL AED Plus™ guides the rescuer through the steps of CPR with voice and graphical prompts, while the ZOLL AED Pro® uses audible and visual prompts on the screen. Additionally, the ZOLL CPR-D padz™ has a sensor that tracks the rescuer's depth and rate as soon as CPR begins. The AEDs deliver voice prompts like "push harder" or "good compressions," while their adaptive metronome leads the rescuer to 100 compressions/minute.

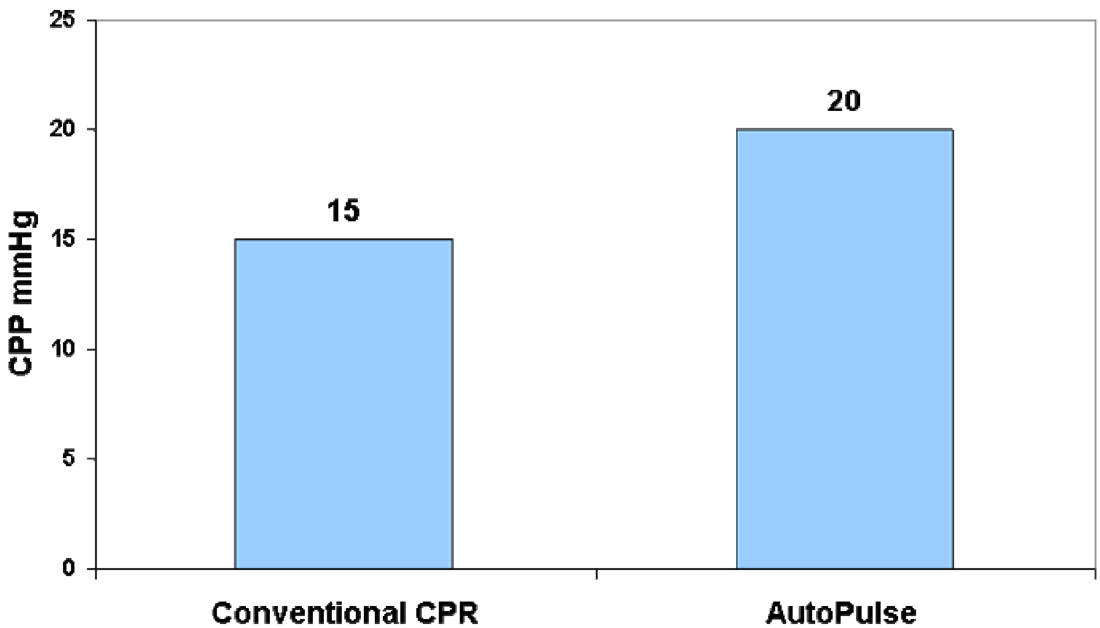


AutoPulse

Clinical devices are being investigated and actually used that generate better hemodynamic characteristics than manual compressions. The AutoPulse® is a non-invasive cardiac support pump that provides "hands-free" compressions over a prolonged time. It is comprised of a backboard and a simple, load-distributing LifeBand® that easily fastens across the victim's chest and moves more blood, more effectively than human hands can possibly do over a prolonged period of time.

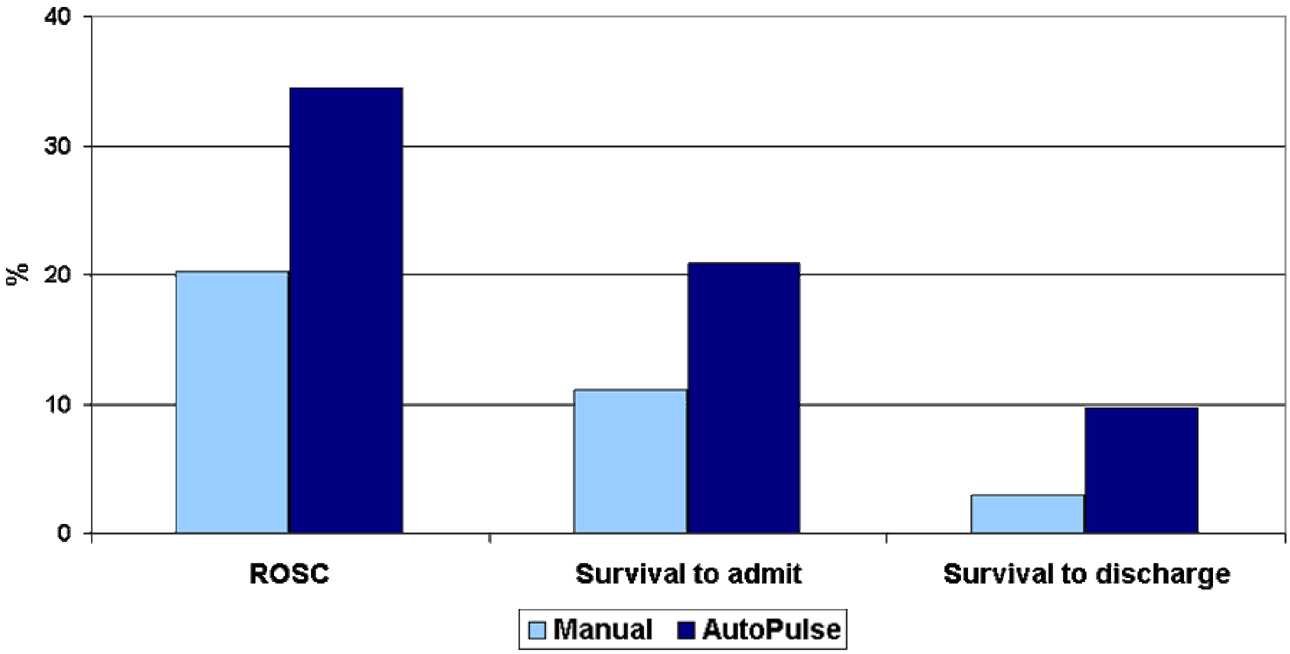
Timerman found that the AutoPulse-generated CPP was 33% better than manual CPR.[10] See figure 4.

Figure 4 - Effect of conventional CPR and AutoPulse on coronary perfusion pressure



Survival studies with the AutoPulse are ongoing. At the AHA Resuscitation Science Symposium in 2005, Ornato reported on a case control study for out-of-hospital cardiac arrest in Richmond. He compared survival rates in 783 patients, 499 treated with manual CPR and 284 with AutoPulse. There was a 71% improvement in field ROSC with the AutoPulse, from 20.2% to 34.5% ($p = 0.0001$). Benefit was greatest in patients who had the AutoPulse applied early and those with VF. The survival to hospital admission rose from 11.1% to 20.9% ($p = 0.0002$), and survival to discharge rose from 2.9% to 9.7% with AutoPulse ($p = 0.0001$).[15] See figure 5.

Figure 5 - Survival with conventional CPR and AutoPulse



The results in the recent cluster randomized, multi-center ASPIRE trial comparing manual CPR to AutoPulse were inconclusive and did not reach statistical significance for 4-hour survival and survival to discharge.[16] The study suffered from implementation and design problems; a new multi-center trial is in the planning phase.

Defibrillation

First responders have the greatest opportunity to provide a successful outcome for victims of cardiac arrest if they are empowered to perform early defibrillation rather than waiting for the CPR team to enact this intervention. Two-tiered defibrillator therapy should be in place within hospitals and ambulatory clinics so that defibrillation can be completed within the expected time interval of 3 minutes from time of collapse. Peberdy reported that of the hospitals participating in the NRCPR in 2002, only 33% had some use of AEDs.[17] Those patients most likely to survive are those with VF, and the longer the delay to defibrillation the less chance of survival.

Staff needs to be familiar with their defibrillators so they can operate them quickly. It is best if defibrillators are unified throughout the organization so they operate off the same platform.

Defibrillators need to be designed so they are easy and intuitive to operate. According to the *2005 Guidelines*, those who are interweaving CPR and defibrillation should:

- Start CPR, and continue CPR while the defibrillation electrodes are being attached.
- Continue compressions while the defibrillator is analyzing and charging until “clear” is announced.
- Give only one shock, and then resume compressions immediately after a shock is given without taking time to check a pulse.
- If a shockable rhythm is recognized, use the manual override button on the AED.

Defibrillators are being redesigned to support these recommendations from the AHA. Motion artifact reduction systems are being developed so compressions can continue during analysis.

Rapid Response Teams

Most patients with non-VF arrests have pre-monitory signs. The CPR team is called at the onset of cardiac arrest, when it’s often too late to treat effectively. With the implementation of Rapid Response Teams, called for early warning signs and symptoms of physiological instability, patients may be “rescued” and cardiac arrest avoided. Increased use of monitors on medical/surgical units may help identify unstable patients and those in VF.

A Model for Resuscitation Teams

Resuscitations in the hospital are always stressful and often chaotic. Responders may have various levels of BLS and Advanced Cardiac Life Support certification. CPR is performed inconsistently and inadequately much of the time. Cooper writes that for the outcome to be favorable the leadership during resuscitation should “initiate structure.” [18] This means that the leader should:

- Let the team know what is expected from them through direction and command.
- Decide what should be done.
- Decide how things should be done.
- Assign group members to particular tasks.
- Maintain definite standards of performance.

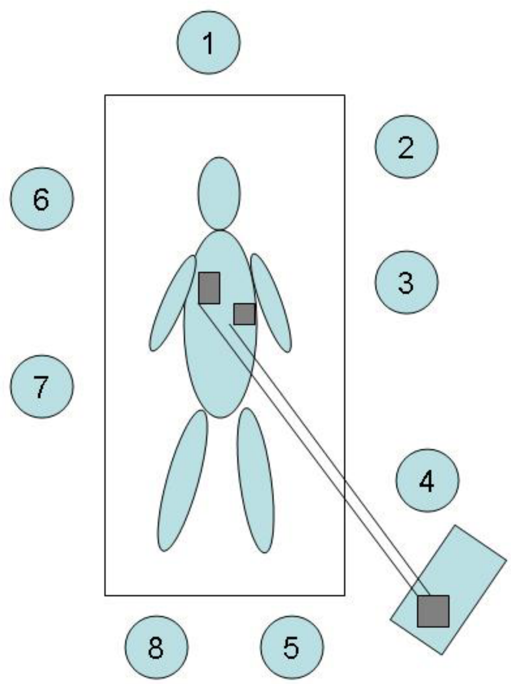
For first responders to initiate structure, it should be immediately determined who will:

- Assess the victim and initiate one-rescuer CPR.
- Call the CPR team.
- Go and get the AED, then attach it to the victim and use it.
- Obtain the arrest cart and other needed equipment.

Once the CPR team leader arrives, if s/he initiates structure early, teams work better together and they also perform the tasks of resuscitation quicker and more effectively. It is now the leader’s role to monitor the performance of compressions and ventilations. It is most effective if the leader stands back using a hands-off approach and does not participate in the interventions so that overall monitoring and guidance can be provided. Staff can be coached to compress fast and deep, minimize interruptions, and change compressors every 2 minutes.

During crisis team performance training, DeVita emphasizes that roles of the CPR team members be clearly defined, with designated positions to stand around the victim’s bed and defined responsibilities.[19] See figure 6. When communicating during resuscitations, determine who needs to know the fact, speak to that person directly, with the receiver repeating the message back.

Figure 6 - Roles, Goals & Positioning for Crisis Team Response



Personnel	Role, Responsibilities
1. Airway	Assist ventilation, intubate
2. Airway Assistant	Assist ventilation, oxygen and suction setup, suction
3. Floor RN	Assess patency of IV's, push meds, defib pads, check pulse
4. ICU RN	Prepare meds, record code events
5. Team Leader	Assess team, assign responsibilities, data, direct treatment, triage priorities, triage to next care site
6. Chest Compressions	Perform chest compressions
7. MD	Perform procedures: IV, chest tubes, ABGs, etc.
8. ICU RN	Data manager: results, chart, interventions

Conclusion

Thus as you implement the AHA's *2005 Guidelines*, it is back to the basics with effective compressions and ventilations. Research has demonstrated that CPR is often performed poorly, resulting in ineffective CPP. Suggestions in this newsletter are given for improving CPR skills, along with other evidence-based resuscitation practice changes to improve outcomes. Monitor the ROSC and survival to discharge statistics so you know if the practice changes you implement make a difference. ZOLL CodeNet®, an electronic resuscitation information management system, can assist you with collecting CPR statistics and analyzing the data for your institution. Then with participation in the National Registry of CPR, you can benchmark your process of care intervals (i.e., time to compressions, time to defibrillation) and outcomes with other organizations. Can we save lives by improving our CPR and defibrillation? We won't know until we measure our results.

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