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Evidence-Based Care for Cardiac Arrest in 2013

Jason T Schaffer, MD
Assistant Clinical Professor of Emergency Medicine
Indiana University School of Medicine
Indianapolis, IN

The 2010 Resuscitation Guidelines were a significant advance in the recommendations for cardiac arrest care. This article takes those recommendations and reorganizes them into a phased approach to resuscitation. The different components of resuscitation and how they apply to each phase will be discussed. The setting and timing of onset of resuscitation impact how we approach a patient in cardiac arrest. The guidelines themselves do not discuss this, as it is the goal of the guidelines to provide an easily teachable standard approach for maximum retention and recall. The phase related approach below is a more complex model that addresses the different pathophysiologies related to the duration of pulselessness.

The theory of the phases of arrest is not well discussed by the guidelines but this theory is not new and is supported by the literature.¹⁻³ These phases make intuitive sense and give us a framework by which to triage our therapies such that they will best impact survival based on the timing of arrest and resuscitation. The 3 phases have been described as - Early: The Electrical Phase; Middle: The Circulatory Phase; and Late: The Metabolic Phase.¹⁻³ To this, we will add Post Arrest: The Cath and Cool Phase.

As part of the discussion, four cases are presented. Each case presents a different stage of arrest or different setting. The following discussion will give a better understanding of prioritizing our interventions for arrest in all scenarios.

Note: This is a discussion of adult arrest not due to special circumstances (i.e. drowning, accidental hypothermia, electrical injuries, etc.).

Case 1: You are the first to respond to a person that has just collapsed and bystanders are calling for help. You assess the person on the ground and note no signs of trauma. He makes a couple gasps during your first 10 seconds at his side but he is clearly unresponsive to any stimuli.

Initiating Resuscitation:

Resuscitation should begin when a person is found to be unresponsive or not breathing normally. The guidelines have eliminated the pulse check for lay responders and, for trained health care providers, have limited the pulse check to 10 seconds. It is clear that both health care workers and lay providers have difficulty determining whether there is a pulse present. Health care professionals may be slightly better at differentiating pulse from pulselessness but we take too much time to make the determination.^{4,5} If the person appears to be in arrest, we are to presume that they are in arrest. This includes unresponsive patients with abnormal respirations, especially gasping type or agonal respirations.

When considering the steps of initiating a resuscitation, the “ABC’s” have been reprioritized. It has been well publicized that the guidelines have changed from the ABCs to the CABs (Circulation-Airway-Breathing). Yet, for experienced practitioners, the ABCs have been so ingrained into resuscitation for so many years that it is decidedly difficult to change that thinking. When we see someone in arrest it is hard not to think “AIRWAY”, especially when we talk about in-hospital cardiac arrest. However, it is becoming increasingly clear that the key to resuscitation is circulation. This is why circulation has been placed first in our resuscitation mnemonic. At the same time, the importance of advanced airway management has been called into question.⁶⁻⁸ Early in arrest, even passive oxygenation associated with minimally interrupted chest compressions may be better than BVM or advanced airway management.⁹ A further discussion of these issues will be carried out below.

Case 2: You are starting your shift in the ED and you just received change-over. You get called to the bedside of an arresting patient. He has been in the ED for 4 hours, and from your change-over discussion you recall that he’s waiting on a bed for a workup of syncope. On your initial assessment, you find him in a pulseless ventricular tachycardia and the nurse at the bedside has just initiated compressions while a second nurse is retrieving the code cart including defibrillation pads and defibrillator.

Early Phase of Arrest: Electrical Phase

The first phase of arrest (within the first 5-8 minutes) is the electrical phase¹⁻³. Early in Ventricular tachycardia or Ventricular fibrillation arrest, the most important component is electricity. Early defibrillation is key.

In the first few minutes of Vfib arrest, the myocardium has relatively full ATP stores and the circulatory system is filled with oxygenated blood. The likelihood of success of defibrillation is highest during this timeframe. Delay of defibrillation for any other maneuvers including pulse checks, airway management, IV access and even excessive compressions may be the difference between failure and success of return of spontaneous circulation (ROSC).

During arrest, because there is no circulation, there is very little oxygen consumption. Until blood flow occurs, the aortic oxygen and carbon dioxide concentrations vary little from the pre-arrest state. Without circulation there is no oxygen exchange at the alveoli; so the lungs will contain the same partial pressure of oxygen as the last breath taken. For these reasons, especially in this early

phase of arrest, airway is unimportant.¹⁰ Compressions should commence immediately while preparations for defibrillation are made,¹¹ but there should be no delay to initiate defibrillation especially in this early phase of arrest.

It has been theorized that compressions prior to defibrillation attempt as a defined course of action may improve defibrillation success.^{5,12,13} There has been conflicting evidence regarding this issue. A recent meta-analysis and systematic review was unable to find a significant difference between immediate defibrillation and delayed defibrillation after a period of compressions.¹² Of the available evidence that suggests that pre-defibrillation compressions may improve outcomes, this benefit was shown when EMS response times were >5 minutes.⁵ This being said, there is no evidence to support delaying defibrillation in lieu of compressions in this stage of arrest.

Electricity:

As mentioned, early defibrillation is key. With each minute of delay in defibrillation, likelihood of survival decreases by 8-10%.² AEDs now make the availability of early defibrillation in the field commonplace and improvements in survival have been shown in multiple prehospital settings with AED use for early defibrillation. For health care providers there may be the availability of manual defibrillators or automatic defibrillators. There is no evidence to support one type over another.

With manual defibrillators, biphasic seems to be preferred but there is no recommendation against monophasic defibrillators. When selecting the energy for defibrillation for biphasic defibrillators, the manufacturer's recommended energy dose should be selected. If that recommendation is unknown, the maximum dose should be chosen. The selection of energy dose and stacking is less important with biphasic defibrillators. These concepts and approaches are held over from the era of monophasic defibrillators where impedance significantly degraded the energy applied. Newer biphasic technology compensates for impedance and the waveform of energy delivered does not degrade in the face of impedance.^{5,14}

Case 3: You are in the ED and a patient arrives at the door brought by family in apparent arrest: cyanotic and apneic. He was not feeling well and family was bringing him in but he stopped breathing about 5 minutes out from the ED. The patient is unresponsive and is transferred to a gurney and compressions are begun. When he is placed on a monitor he is noted to be in ventricular fibrillation.

Middle Phase: Circulatory Phase

The second phase of arrest (the next ~5 minutes) is the circulatory phase¹⁻³. The early phase of arrest is ending and the optimum timing for lone defibrillation is passing. ATP stores are being depleted by the fibrillating myocardium; thus the myocardium is no longer primed for defibrillation.¹⁵ Metabolic byproducts and waste are beginning to build up. However, the stagnant blood in the systemic circulatory system still contains adequate oxygen stores, as oxygen exchange is minimal without circulation. Restoring coronary and cerebral perfusion with

compressions is key to neurologically intact survival. The brain is suffering the same consequences of stagnant blood flow as the myocardium.

Compressions are paramount in this phase. By circulating the oxygenated blood the myocardium can begin to again utilize oxygen, restore ATP¹⁵, and improves the metabolic milieu in the myocardium by carrying away byproducts of the fibrillating heart. The restoration of blood flow improves the likelihood that a defibrillation attempt will be successful. For this reason, there are those that argue for compressions prior to first defibrillation attempt for all arrest patients. Although this is a contentious topic, this argument may be best placed during this phase.

Circulation:

With over 60 years of CPR and of all the successes and failures of trying to improve outcomes, it appears that the intervention with the most impact on survival along with early defibrillation is also the most basic: compressions. All components of arrest care are necessary for success, but by optimizing and being consistent with compressions along with use of early defibrillation, we can greatly impact survival. This is true in both the hospital and prehospital setting.

The support for this statement comes from multiple studies. The evidence is not all direct but the volume of indirect evidence speaks loudly to this point. From Cardio-Cerebral Resuscitation and Hands-Only CPR and other studies,^{4,10,16–21} it is apparent that effective compressions and maximizing time doing compression during resuscitation is key. Cardio-Cerebral Resuscitation (CCR) is defined as 200 compressions followed by a single shock and 200 compressions. CCR has been shown to be superior to conventional CPR for neurologic survival in 2 different studies especially in the arrest population with shockable rhythms. In 2006, Kellum et al. presented the rural Wisconsin prehospital experience in which changing from CPR to CCR resulted in an improvement of neurologically intact survival from 15% to 48%.¹⁶ Bobrow et al. also showed significant improvements in survival in the prehospital setting in metropolitan areas in Arizona. There may be several variables responsible for these successes, but a large component of each of these protocols is increased time doing compressions.

Consistency in compressions is essential, yet multiple studies have shown that we spend much of our time in resuscitations completing tasks other than chest compressions. Before the Hands-Only CPR campaign and the 2005 and 2010 guidelines, at least 2 studies assessed the quality and consistency of compressions in the field. A Northern European study found that compressions were only performed during 48% of the total pulseless time in resuscitations.²² In Tucson, Arizona at about the same time, researchers found that compressions were performed during only 43% of the total resuscitation time.²³ It appears that in-hospital, we do not perform much better. We have frequent interruptions for airway (up to 7 minutes in one study) and apply suboptimal compressions (inadequate depth and/or rate) up to 40% of the time.^{24–27}

Quality of compressions is an issue as well. The Northern European study found an average of 64 compressions per minute. These compressions reached the recommended depth in only 28% of the cases.²²

While minimizing the number of pauses is important to survival, each pause itself may even be detrimental. Evidence in swine models shows that pauses in compressions can break the momentum of blood flow and that there is a lag-time for that momentum to be regained when

compressions are resumed.^{3,29} This may impact adequate coronary and cerebral perfusion pressures. In one study however, this circulatory momentum evidence did not seem to translate to humans.³⁰ The significance of short pauses is unclear at this point, but it is clear that pauses must be kept to as few and as short as possible. Longer pauses do negatively impact the response to shock and neurologic outcomes.²¹

In an effort to improve consistency of compressions there has been significant interest in hands-on defibrillation and its safety. The safety of hands on defibrillation is likely possible with standard hospital gloves and biphasic defibrillators, but this has not been proven as of current evidence.^{31–33}

Chest compression devices have been shown to elicit quality compressions at guideline recommended depth and rate.^{34,35} However, no mechanical compression device has been shown to improve outcomes. There may be specific circumstances where they could be used as a good alternative to manual compressions but are not recommended for routine use in resuscitations.^{34,35} Issues with their use include availability and time to placement.

The official guideline recommendations for optimal compressions are as follows:

- Rate of 100/minute
- Minimally interrupted
- Depth of at least 2 inches
- Immediately before and after shock
- Change of rescuer at 2 minute intervals

Airway

Even though oxygenation becomes more important during this phase, invasive airway control may still not be indicated. However, ventilatory assist is recommended via bag-valve-mask if possible. Accordingly, the 2010 guidelines recommend that definitive airway should only be considered after 3 cycles of compression-defibrillation attempts.⁵ And, again, even at this juncture, there are some that question the benefit of a definitive airway over bag-valve-mask.^{6–8}

Why did the Airway get demoted?

First, there has never been any evidence to support the initial breaths that were once taught in the ABC's of CPR. Considering the circumstances of most VTach and VFib arrests as a primary cardiac event, initial breaths do not make sense. As stated earlier, without circulation, the lungs and blood should be in the pre-arrest state. Defibrillation and circulation should be the primary interventions: the order depending upon the timing of arrest and intervention, and available resources. Thus the initial breaths have been removed from the guidelines.

Second, advanced airway interventions may be detrimental to resuscitation. The most obvious and important reason for this is that it takes time to intubate. The interruption of compressions and resuscitation for advanced airway management procedures is significant. Both prehospital and in-hospital studies have shown this to be true.^{23,25–27}

Third, although some evidence supports early advanced airway,^{36,37} the newest evidence shows that passive oxygenation and BVM may be superior to advanced airway management, especially early in arrest, in both prehospital^{6,38} and in-hospital settings.³⁶ The reason for this may be related to breathing mechanics and the negative effect on adequate circulation provided by compressions. This will be discussed further in the *Breathing* section below.

There is no definitive evidence at this time to dictate when to place an advanced airway in arrest patients. It makes sense that down time, resuscitation time, and setting (including number and skill of providers and likely causes of arrest) may dictate timing of advanced airway placement on a case-by-case basis. For example, with presumed respiratory source of arrest, early intubation may be critical. However in true V-fib/V-Tach arrest, passive oxygenation and minimally interrupted chest compressions may lead to more survival. We, as the experts, must make this determination on a case-by-case basis. What seems to be clear however, is that intubation does lead to significant delays/interruptions of compressions.^{23–27} We must take this into consideration when deciding between intubation and other less definitive advanced airways.

Breathing

Breathing during resuscitation delivers oxygen to the lungs and thus the circulation via chest compressions. This beneficial effect is of significant importance, especially as time moves on during a resuscitation. There are other effects of breathing though that may not be so obvious and may be deleterious to the resuscitation. These can be seen with advanced airways as well as with BVM breaths and mouth-to-mouth breaths.

In single person (i.e. bystander) resuscitation, time spent breathing is time without circulation. The benefits of circulation and compression-only CPR were shown in the SOS-KANTO trial in 2007 and has been the focus of the Hands-Only CPR campaign. This trial demonstrated similar (6% vs 4%) favorable neurologic outcome at 30 days with bystander hands-only resuscitation versus conventional CPR.²⁸ These benefits may be based upon the continuous provision of circulation but may also be present because of the lack of the deleterious effects of breathing on the circulation.

During chest compressions, perfusion depends not only upon the positive intrathoracic pressure from the compression pushing blood out, but also depends upon the negative intrathoracic pressure of the recoil of the chest which causes cardiac return of blood. This recoil and resulting cardiac return is as important as the compression itself.³⁹

Expansion of the chest with an active breath significantly increases the intrathoracic pressure over the period of that breath. This decreases the time during which there is negative intrathoracic pressure and thus decreases cardiac return. Thus every breath delivered decreases cardiac return and decreases the resulting perfusion. This effect is seen with optimized breathing during resuscitation but is worsened when breathing is not optimized.

For example, hyperventilation often occurs during the tense moments of a resuscitation. The increased time spent breathing decreases the time with negative intrathoracic pressure even more.³⁹ Another related problem occurs when the breaths may be given at the appropriate rate but each breath is given over a prolonged period of time. Again in this case, the time with negative intrathoracic pressure is decreased significantly which again decreases cardiac return.³⁹ Thus

rescue breaths should be given with a rapid insufflation of the lungs to allow for a shorter period of time with positive intrathoracic pressures due to breathing. A third problem can be seen when too large a volume of air/oxygen is given with a breath. For this reason the optimal respiratory rate during resuscitation with rescue breaths is 8-10 breaths/minute.⁵ Volume and breathing rate need to be closely monitored as well.

Device makers have attempted to leverage the intrathoracic pressure and it's effect on the hemodynamics and cardiac return. An impedance threshold device (ITD) can be attached to the ET tube or mask to limit the airflow into the lungs. This limits the positive intrathoracic pressure. The ITD by itself has not been shown to improve outcomes. One ITD has been shown to improve neurologic outcome when used with an active compression/decompression device. The compression/decompression device has a suction cup to allow the rescuer to both push and pull on the chest. The improvement in survival was modest yet statistically significant.³⁹ The active compression/decompression device is not yet approved for use in the United States.

Case 4: You are the first trained medical provider to arrive on the scene of a patient in arrest. He has been unresponsive for >10 minutes.

Late Phase: Metabolic Phase

The late phase is the metabolic phase.¹⁻³ Even in a stagnant state, blood is now fairly deoxygenated. With appropriate compressions, circulation may still be helpful with carrying away metabolic waste but without significant supplemental oxygen, the blood is becoming more and more deoxygenated. Metabolic waste is building up in cells, and the myocardium is almost certainly lacking the necessary ATP needed for function and defibrillation. Circulation is still necessary and oxygenation may be more important, but by now these will not likely be enough. In this phase, medications are likely necessary for ROSC.

Medications

Aggressive resuscitation including early defibrillation and consistent compressions are the mainstay of treating patients with cardiac arrest. These 2 components have been shown to increase the likelihood of survival and neurologic outcomes. On the contrary, the use of medications during the application of ACLS has not been shown to improve long term outcomes. Short term outcomes and survival to hospital have been shown to have some improvement with epinephrine⁴⁰ and amiodarone⁴¹ in the prehospital arena, but survival to discharge and neurologic outcomes have not been affected. It can be argued that getting patients to the hospital is the first step in the chain of survival, and that by taking this first step with more arrest patients will lead to more survival, however current evidence for medications has shown no impact beyond admission.

It is possible that as we learn more about each link in the chain of survival that future evidence will better support the use of medications. Additionally, there has been no evidence to show direct harm from these medications. With these two premises in mind, it is important to discuss the current role of medications in resuscitation.

In the only epinephrine versus placebo trial, ROSC (Odds Ratio = 3.4, 95% CI = 2.0–5.6, $p < 0.001$), and survival to admission (Odds Ratio = 2.3, 95% CI = 1.4–3.6, $p < 0.001$) were improved by epinephrine. Despite these clear benefits, epinephrine did not improve survival to discharge, nor neurologically intact survival.^{40,42} Epinephrine seems to bring improvements in ROSC; however, epinephrine does not seem to improve neurologic survival.⁴² It is unclear what role epinephrine (and other medical therapies) will play in the future for cardiac arrest. It is possible that over the next several years we begin to better link the chains of survival. It is also just as feasible that we discover that despite short term benefits of ROSC, epinephrine may lead to worse long term survival and/or worse neurologic outcomes. For now, epinephrine is still standard of care in arrest and recommended by the guidelines, at a 1mg dose every 3-5 minutes.⁵ High dose epinephrine has been examined and has not shown any significant benefit to survival or neurologic outcomes and is not recommended.^{5,43}

The only other vasopressor recommended in the guidelines is vasopressin. In theory, vasopressin has some benefits over epinephrine in that it is a strong peripheral vasoconstrictor which shunts the circulating blood via compressions centrally. However, it has no direct stimulatory effects on myocardial activity and thus does not increase myocardial demand. Several studies have evaluated vasopressin versus epinephrine and there appears to be no significant benefit of vasopressin over epinephrine despite its theoretical advantage. There appears to be no harm, however, and it may be beneficial in certain circumstances such as refractory VF or pulseless VT. It is recommended by the AHA as a one-time alternative to epinephrine (vasopressin 40 Units IV).^{5,44}

Atropine has been removed from the guidelines for cardiac arrest. There is no evidence of benefit for this medication in cardiac arrest.^{5,44} There is data to support its use in pre-arrest states, specifically in bradyarrhythmias.^{5,45,46} Its use in this setting may prevent the deterioration to arrest states with improved perfusion.

Evidence and recommendations in regards to antiarrhythmic medications have not changed. There is evidence to support amiodarone for refractory VF and pulseless VT. One study has shown improved survival to admission with the use of amiodarone vs lidocaine, but neither has shown an increase in survival to discharge nor improved neurologic survival.⁴¹ Based on a retrospective review, there is an association with increased survival to admission with lidocaine but there is no direct evidence to support its use.⁴⁷ Again, it is unclear at this point whether bringing more people to the door can lead to better rates of survival. Based on this data however, the guidelines recommend amiodarone (300mg IV with a second dose of 150mg IV after 5 minutes). The 2010 guidelines stop short of eliminating lidocaine altogether based on its familiarity and lack of side effects, and they list it as an alternative to amiodarone if amiodarone is not available.⁵

It is interesting to note that all of the medications listed above, have been given a recommendation of “Class IIb” meaning that the benefit is greater than or equal to the risk and the treatment may be considered. Even atropine is cited in the guidelines as having a recommendation of class IIb and yet it was removed from the guidelines. This emphasizes the point that good resuscitation care is based on compressions and early defibrillation; medications are adjuncts that are not necessarily supported by significant evidence.

Post Arrest Phase

The post cardiac arrest phase is a syndrome much like sepsis is a syndrome. ROSC is just the beginning and with the return of circulation the real work of resuscitation must now start. A full discussion of post-ROSC care is beyond the scope of this article; however post arrest care is important in that it may make the difference in maintenance of spontaneous circulation, short and long-term survival, and neurologic recovery.

We need to have clear goals for post arrest care. These can be thought of similarly to the well-publicized Early Goal Directed Therapy for sepsis.⁴⁸ The inciting event for the arrest and underlying disease must be at the forefront of our minds as we work through the next steps of resuscitation. Each of the following principals may not apply to all patients but should be considered with each post arrest patient.

1. First, optimize hemodynamics. The early focus should be obtaining a good mean arterial pressure by utilizing fluid resuscitation where appropriate and potentially utilizing vasopressors (understanding that some vasopressors may exacerbate underlying arrhythmias).
2. As post arrest care continues, the focus should include urine output, ScvO₂, and lactate clearance as a measure of tissue perfusion and ischemic recovery. Similarly, we need to optimize oxygenation and ventilation. The goal should not be an oxygen saturation of 100%. Hyperoxia increases the risk of free radical formation and can worsen the metabolic derangements, specifically in the CNS, and have deleterious hemodynamic effects. Post arrest ventilation with 100% O₂ even within just the first hour has been shown to result in worse neurologic outcome versus FIO₂ adjustment to produce oxygen saturations of 94-96%.^{48,49}
3. Early post-arrest ECG is recommended.^{50,51} Overall the most common cause of cardiac arrest is cardiovascular disease and coronary events. One study looked at patients without obvious non-cardiac cause of arrest. In this study, 96% (128/134) of patients with ST Elevation post ROSC had at least one significant coronary lesion. In the same study however, 58% (176/301) of patients with *no* STE on their post arrest ECG had at least one coronary lesion as well.⁵² Patients with STE post ROSC should be treated like STEMI patients and taken immediately to angiography. We should also have a low threshold for early catheterization in patients if no clearly identifiable non-cardiac cause exists whether there is STE or not, but especially with any pattern of injury on ECG.
4. Therapeutic hypothermia is indicated for patients who are post-ROSC from VF rhythm who remain comatose. There is less evidence to support hypothermia for patients recovered from PEA or asystole but this may still be considered in these patients.⁵⁰

Some have advocated for protocols that include early catheterization and hypothermia for all post-ROSC patients. They have shown an increase in one-year survival, 47% vs 28%, after the initiation of these protocols in patients with witnessed out of hospital cardiac arrest and shockable rhythms.⁵³ Similarly, Stub et al. showed increased survival and neurologic outcomes with an aggressive PCI + Hypothermia post arrest protocol.⁵⁴ It is not clear that these successes can be duplicated at this point and clearly not all centers have the resources for such protocols. However, successes like these do argue for aggressive post ROSC care and raise the question of “can we do better?” The answer appears to be “Yes!”

Conclusions

As emergency medicine physicians, we are the experts in this field. As the experts, it is important for us to have an understanding of the AHA guidelines and what they say. It is also vitally important for us to have an understanding of the theory and the available evidence. We need to have a mastery of this evidence to where we can teach these guidelines to providers of all levels to make the greatest impact on survival in each of our communities. We should be able to teach the layperson that Hands-Only CPR is safe and effective, our lawmakers that public health campaigns make large impacts in getting patients to hospital with a pulse, and our fellow health care workers of all levels of the vital importance of compressions.

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