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Introduction

Advances in cardiac & resuscitation call for new EMS field practices

Cardiac, respiratory and resuscitation medicine is rapidly changing with new protocols, procedures, thought processes, treatment devices, training and operations. More importantly, research and resuscitation outcomes are validating new approaches to care and driving new approaches to resuscitation. Consequently, care in the field must adapt.

This EMS State of the Science supplement, developed in cooperation with the U.S. Metropolitan Municipalities EMS Medical Directors Consortium and our sponsors, features articles that address key resuscitation issues.

In “The Sweet Spot,”Ahamed H. Idris, MD, director of the Dallas Fort-Worth Center for Resuscitation Research at UT Southwestern Medical Center, demonstrates that the delivery of uninterrupted, quality compressions is crucial to patient resuscitation, but also that the likelihood of ROSC after out-of-hospital cardiac arrest is greatest with chest compression rates between 100–120 compressions/minute and that ROSC declines when compressions exceed 125 compressions/minute.

The current state-of-the-science in cardiac care is presented in “Trends & Changes in Cardiac Care,” authored by Vanderbilt University’s Corey Slovis, MD, FACEP; Jared McKinney MD; and Jeremy Brywcynski MD, FAEM. Areas discussed include the importance of first responder AED use; optimal CPR and new perspectives on ventilations and compressions; metronomes; mechanical CPR devices; the impedance threshold device; and transportation of ROSC patients to resuscitation centers.

“Q&A with Joan Mellor” is an informative interview with the program manager for the Medtronic Foundation’s HeartRescue Project, which is working to improve cardiac arrest survival by 50% over five years. The interview details how they plan to develop and expand their SCA response systems by coordinating measurement, education and training among the general public, first responders, EMS and hospitals.

David P. Keseg, MD, FACEP, medical director for the Columbus (Ohio) Division of Fire, tackles CPR delivery methods in “The Merits of Mechanical CPR.” Although some controlled trials and studies have reported insufficient evidence to draw conclusions about the benefit of mechanical chest compressions during CPR, Dr. Keseg points out that many EMS systems are having positive results and increased ROSC using these devices in conjunction with updated and regimented resuscitation processes.

Finally, in “Depth Perception,” author Kathleen Klein points out that compression depth is one of the main determinants of coronary perfusion pressure, which in turn is a primary predictor of patient survival. She then introduces us to triaxial field induction (TFI) technology, which will assist crews in compressing patients to the appropriate depth by measuring and displaying the relative distance via a chest sensor and a reference pad placed under the patient.

As with all JEMS editorial supplements, this EMS State of the Science supplement presents the latest information by outstanding authors, and also backs up the information with the more than 140 footnoted references for the most current research in each area. Read each article carefully and share this important information with your staff.
The Sweet Spot

Chest compressions between 100–120/minute optimize successful resuscitation from cardiac rest

The quality of CPR and chest compressions are key factors for survival from cardiac arrest. Over the past 50 years, there has been a progressive increase in the recommended rate of chest compressions during CPR.

In 1960, the recommended rate was 60 compressions/minute; this increased to at least 100 compressions/minute in the latest guidelines from the American Heart Association (AHA) in 2010. However, guidance is not provided for a maximum chest compression rate.

In this article, I’ll review key studies and gaps in our knowledge about chest compression rate, including the study recently published in the journal Circulation and how it can be used to guide clinical practice. I’ll also review what further studies need to be done regarding chest compression rate and quality of CPR in general.

One of the most fundamental things that we have learned from research over the past 10 years is that survival from out-of-hospital cardiac arrest depends mostly on the quality of BLS (including defibrillation) that is given in the field before the patient arrives at a hospital. In Dallas-Fort Worth, and at least one other Resuscitation Outcomes Consortium (ROC) site, less than 1% of patients who are not resuscitated in the field will leave the hospital alive.

DISCOVERING THE QUESTION

The AHA and the International Liaison Committee on Resuscitation (ILCOR) jointly review guidelines for CPR every five years to determine if new science published since the last review provides evidence strong enough to...
justify changing a guideline or adding a new guideline.

In 2006, AHA and ILCOR asked me and two other investigators to review the guideline for chest compression rate during CPR in preparation for the 2010 CPR Consensus on Science Conference (the last CPR guidelines had been published in 2005).

I began the review of chest compression rates by searching for appropriate articles in such databases as PubMed and repeated it several times until November 2009. The final review included 22 articles that were a variety of human, animal and manikin studies, few of which tested different chest compression rates. The studies showed that when compression rates of EMS providers were measured in the prehospital setting, the rates were faster than 100 compressions/minute, generally averaging about 110–120 compressions/minute.

Animal studies showed that blood flow and survival increased with faster chest compression rates. Some studies compared 60 with 120 compressions/minute and some compared 60, 100, 120 and 150 compressions/minute. These studies showed better blood flow occurred at 120–150 compressions/minute. One animal survival study compared 60 and 120 compressions/minute and found greater survival with the faster rate.

Two human studies compared 80 with 120 compressions/minute. These studies found improved blood flow and pressure, or increased end-tidal carbon dioxide levels (an indirect measure of blood flow), with the faster rate.

In summary, these studies provided consistent evidence for improved blood flow at rates of 120–150 compressions/minute. However, this is only indirect evidence regarding optimal rates because none of the studies observed the influence of chest compression rates on return of spontaneous circulation (ROSC), or survival, in humans.

The bottom line: This was a huge gap in the scientific literature of resuscitation for something as fundamental as chest compression rates during CPR.

Identifying gaps in scientific knowledge is one of the functions of the guideline review process, so that investigators can be directed to important areas of future research. The review prompted me to take up the question: What is the ideal chest compression rate range (low and high) for survival?

METHODS
Fortunately, as an investigator in the ROC, I was in a position to do something about it. The ROC is a network of regional research centers that are focused on two main problems: severe traumatic injury and non-traumatic cardiac arrest. The regional research sites include:

- Birmingham, Ala.
- Dallas-Fort Worth
- Milwaukee
- Pittsburgh
- Portland, Ore.
- San Diego
- Seattle-King County
- Ottawa, Ontario
- Toronto, Ontario
- Vancouver, British Columbia

The ROC maintains a registry for cardiac arrest that was started in December 2005 and continues today. The registry enrolls about 22,000 out-of-hospital cardiac arrest cases annually. Such patients receive CPR by paramedics and firefighters and are then often transported to a hospital. The registry data starts with the 9-1-1 call and ends with vital status at the time of hospital discharge, including in-hospital data.

Most importantly for my study, the registry collects data from electronic files that defibrillator-monitors record during CPR. These files record chest compressions, shocks, and interruptions in chest compression and some also record the depth of each chest compression, ventilation, and end-tidal carbon dioxide. The files are a detailed record of the entire resuscitation and are the next best thing to actually being there (possibly better than being there because of the detailed second-to-second measurements found in these files).

These files have provided crucial data that has been used in a number of studies regarding various aspects of CPR, including chest compression rates, which collectively can be termed "quality of CPR" studies.

Our study of chest compression rates included more than 3,000 adult patients from ROC sites in the U.S. and Canada who had out-of-hospital cardiac arrest and CPR provided by EMS rescuers (firefighters and paramedics). All of the study patients had electronic recordings of chest compressions available.

The study included data from the first five minutes of CPR; this data was analyzed using a logistic regression model. The model adjusted for the following factors that are known to affect outcome:

- Age
- Sex
- First known rhythm
- Witnessed cardiac arrest
- Bystander CPR
- Location (home vs. public)

These factors are also called Utstein predictors and should be used in most cardiac arrest studies where outcome is an end-point.
The model also adjusted for ROC site. Chest compression rate was measured only during intervals when chest compressions were being performed and excluded intervals in which there was a pause in chest compressions.

Average patient age was 67 years; 1,082 had ROSC (35%) and 265 (8.6%) survived to hospital discharge. The study found that the average chest compression rate used by EMS providers across ROC sites was 112 compressions/minute. One-third of patients received a rate greater than 120/minute, and 7% had a rate greater than 140/minute. Remarkably, we measured rates up to 180 compressions/minute at many sites.

**Significant Results**

We found that ROSC peaked at a chest compression rate of about 125 compressions/minute and then declined sharply at higher rates (Figure 1). In addition, survival-to-hospital discharge also peaked between 100–120 compressions per minute and then declined at faster rates, although this was not statistically significant after adjustment for the covariates listed above (Figure 2).

Another important finding: Chest compression depth became less as chest compression rates became faster, especially with rates above 140/minute. Adequate depth of chest compressions is thought to be a very important determinant of outcome from cardiac arrest; so loss of depth at high compression rates may be one mechanism accounting for the decreased success of resuscitation.

Two principal mechanisms are thought to be responsible for producing blood flow during external chest compression: direct cardiac compression and increased intrathoracic pressure. In either case, forward blood flow depends on venous blood filling the heart or lungs during diastole or the release phase of external chest compression. If this phase is too brief, blood available for forward flow during the compression phase will be limited.

Such mechanisms may account for findings in animal models and in the present study that 120 compressions/minute is a rate that appears to be optimal for blood flow as well as for survival, but that rates faster than 120/minute are associated with decreased blood flow and survival.

Implicit in the guidance for rescuers to “push hard, push fast” may be the belief that rescuers don’t push hard enough. That they don’t push hard enough has been documented in a number of studies. However, at least for professional rescuers, the tendency is to push too fast. This tendency may be because of the surge of...
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adrenaline and excitement that occurs during a code, but may also be a function of the elastic properties of the human chest, which makes higher chest compression rates feel more natural to the rescuer. This phenomenon may be similar to the natural bounce frequency of a trampoline. Thus, compressing the chest at a frequency of 100–120 compressions/minute may require a conscious effort to counteract higher compression rates that seem more natural.

Metronome devices that emit a tone can be set to a desired rate to provide guidance during chest compression. Metronomes have been found useful as an aide to maintain correct chest compression rate. We have used metronomes in Dallas EMS agencies with great success. We measured chest compression rates for several years and found it to average about 135 compressions/minute.

After we introduced metronomes on all EMS AEDs and monitor-defibrillators, the average rate decreased to 107 compressions/minute, a rate that’s right in the middle of the cardiac compression “sweet spot.” This improvement in chest compression rates and other aspects of basic CPR coincided with a substantial increase in survival rates in Dallas.

Moreover, we have been teaching lay rescuers to use the song “row, row, row your boat, gently down the stream” (first proposed by my colleague Ray Fowler, MD) as an aide to help maintain the proper chest compression rate. Almost everyone knows this song and we have found that it aids in calming some rescuers during a stressful event, such as cardiac arrest.

FUTURE STUDIES
This compression range study should be repeated with a larger number of patients with data from electronic CPR files to determine if chest compression rate is significantly associated with survival to hospital discharge. A study with sufficient power to determine optimal chest compression depth for survival should be also be conducted.

Optimal chest compression rates may also differ depending on whether manual compression is performed or whether a mechanical chest compression device or a device that affects circulation during chest compression is used. Such devices should be studied to determine optimal chest compression rates.

Studies addressing the following questions are also needed: When should ventilation be started during CPR, and how much ventilation is needed to improve survival to hospital discharge?

CONCLUSION
Although additional studies are needed, this study shows that the likelihood of ROSC after out-of-hospital cardiac arrest was greatest with use of chest compression rates between 100–120 compressions/minute and ROSC declined when compression exceeded 125 compressions/minute.

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REFERENCES


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Maintaining the proper depth and rate of compressions has been shown to be crucial to the success of resuscitation.
The state-of-the-science in cardiac care and resuscitation is constantly evolving. American Heart Association (AHA) resuscitation guidelines, clinical trials, prehospital protocol revisions, equipment innovations and recent research are changing the way we provide care in the field. More importantly, many new recommendations and studies are making an impact on our ability to improve resuscitation outcomes. This article will address several of the major impact areas.

THE IMPORTANCE OF FIRST RESPONDER AED USE
Out-of-hospital cardiac arrest (OHCA) is one of this nation’s biggest public health concerns. Although the outcomes seen in patients with an initial rhythm of asystole or EMD/PEA continue to be poor despite recent advances in ACLS and post-arrest care, the potential for survival to hospital discharge in VF/VT arrests is much higher. However, time is of the essence. It is well known that there is a 5–10% decrease in survival for every minute delay in defibrillation in patients suffering from VF/VT cardiac arrest. That has generated a push for communities to increase the deployment of AEDs in the hopes that the public will more actively participate in the chain of survival and decrease the time to defibrillation.

Investigators from the Resuscitation Outcomes Consortium evaluated the potential survival benefit from AED application prior to EMS arrival.1 Out of 13,769 patients, 289 had an AED applied prior to EMS arrival and survival was almost double with application of an AED. Although AEDs are extremely easy to use, the problem is that they are often not applied by the public even.

Intraosseous devices, such as the EZ-IO, speed up the delivery of fluid boluses and medications.
when readily accessible. A widespread study of first responder AED use was reported in a 2002 article published by Myerburg et al in which the impact of police vehicle deployment of AEDs was evaluated. In that study, police were first to arrive at 56% of cardiac arrest calls for which a dual dispatch was initiated. Survival to hospital discharge was 17.2% in patients found to be in VF/VT in the police-AED program vs. just 9% in historical controls.

Out-of-hospital VF/VT arrests represent the group that stands to benefit the most from programs that increase awareness of cardiac arrest as well as the importance of bystander CPR and early defibrillation. Even though there is significant cost inherent to such a process, communities must continue to place AEDs in high-yield public locations and encourage public access defibrillation.

OPTIMAL CPR & NEW PERSPECTIVES ON VENTILATIONS & COMPRESSIONS

For many years, the concepts of “intubate, oxygenate and hyperventilate” were thought to be essential to maximizing survival from cardiac arrest. Securing the airway with an endotracheal tube along with aggressive ventilation with 100% oxygen were thought to be the key to performing expert CPR, while compressions were to be done as best as possible when not trying to intubate or defibrillate.

Similarly, giving mouth-to-mouth respirations to pulseless patients was thought to be “required” in order to help save a life before EMS arrived. Between the fear of not doing mouth to mouth correctly and concerns over patient regurgitation; contracting an infectious disease, such as hepatitis, TB or HIV; or not having a CPR card, most OHCAs did not receive bystander CPR.

Much has changed as new results have shown that a simplified approach to both bystander- and EMS-provided CPR can dramatically improve survival of neurologically intact individuals. It is essential that all of us be expert in what works and what doesn’t if we are ever going to significantly improve our current overall CPR survival rate above 8%.

What is now known is that compressions-only CPR works at least as well (if not better) as traditional compression and ventilation CPR. It is also very clear that performing compressions only, without devoting time and attention to ventilations, is much easier to teach and perform.

In a recent study from Australia, lay rescuers were taught over the phone during an arrest to begin their resuscitation efforts with 400 compressions and their results were compared to a group receiving traditional CPR with both initial ventilations and compressions. Compressions-only CPR increased the likelihood of CPR being performed and also increased survival to hospital discharge in VF/VT patients by 40%, from 21% to 29%.

This protocol, which is now advocated by the Medical Priority Dispatch System (MPDS), does recommend ventilation begin at a ratio of 2 per 100 compressions, but only after four minutes of compressions.

Additional support for doing compressions-only CPR comes from the SOS-KANTO trial, where good neurologic outcome was 2.7 times more likely if ventilations were withheld.

Although there is now general agreement that compressions-only CPR is optimal for the general public, how EMS should initially perform CPR is more controversial. Services that follow traditional practices of early ventilation and intubation for victims of cardiac arrest should carefully consider whether this is still appropriate, especially in patients with shockable rhythms.

An important study appeared in 2009 from the Tucson and Phoenix Fire Departments that compared two methods of ventilation in more than 1,000 cardiac arrest patients. Patients either received slow bag-valve mask ventilations or passive oxygenation with just a non-rebreather face mask applied. In those patients with witnessed VF/VT, passive oxygenation improved survival by about 50%; unfortunately, no survival benefits were seen in un-witnessed arrests or patients with non-shockable rhythms.

The benefits of not providing early ventilation appear two-fold: First, not ventilating avoids the resultant rises in intrathoracic pressure that might impede venous return, thus no ventilations have the potential to increase cardiac output. Second, by focusing on compressions only, rescuers can increase the percent of time they are on the chest performing compressions. This chest compression fraction must be maximized in order to optimize survival.

Although it’s clear that compressions should be begun immediately post arrest, and that ventilations need not begin immediately, two other issues are yet to be resolved: (1) whether patients in VF/VT should be defibrillated as soon as possible or receive compressions for 2–4 minutes pre-shock and (2) whether cardiac arrest patients should be endotracheally intubated at the scene.

An immediate shock is indicated in witnessed arrests, and those in which the downtime is less than 4–5 minutes. Some have suggested in those patients with unwitnessed arrests, which are likely in excess of 4–5 minutes, compressions-only CPR for 2–3 minutes may improve survival. This is because in patients with prolonged downtimes, compressions may circulate oxygenated blood through the coronary arteries and mitigate some of the anaerobic metabolic derangements of prolonged pulselessness. However, both a recent study and Cochrane Database Systematic Review have shown that delayed defibrillation has no advantage to immediate defibrillation.

Thus, we endorse a single, simple protocol that focuses on rhythm analysis and defibrillation as soon as possible. This is more easily taught and implanted rather than one that requires judgment and an estimation of downtime.

EMS must also make informed decisions on how to...
manage an airway once ventilations are begun. It is no longer universally accepted that early endotracheal intubation optimizes survival in cardiac arrest patients. In an analysis of all the available literature up to 2009, the Cochrane Collaboration, concluded that "in non-traumatic cardiac arrest, it is unlikely that intubation carries the same life saving benefit as early defibrillation and bystander cardiopulmonary resuscitation."26

Multiple retrospective studies comparing routine ETI vs. either bag mask ventilation or early use of a supraglottic airway, such as a Combitube or King Airway, have demonstrated increased survival with delayed or no attempted intubation.16–20

A recent study from the Mecklenburg (N.C.) EMS System showed that using a King LT-D supraglottic airway resulted in a significantly higher first attempt success rate when compared to trying to insert an endotracheal tube.21

There are many reasons why definitely securing the airway with an endotracheal tube may not be optimal in the early phases of an attempted cardiac resuscitation. First, compressions may be interrupted when ETI is attempted. Other reasons include increased potential for hyperventilation, inadvertent esophageal intubation and difficulty intubating, which may delay other therapies and compromise or interrupt compressions.22

Thus, supraglottic airways (SGAs) offer many potential benefits over endotracheal intubation. They can be inserted faster, do not require visualizing the trachea, do not interrupt CPR and have a much higher degree of first pass success.23

However, very recent evidence is casting doubt on the potential superiority of SGAs. In a retrospective evaluation of an ROC study involving more than 10,000 patients, ETI improved survival to discharge when compared to SGAs (4.7% vs. 3.9%; OR: 1.40).24 The reasons for decreased survival from the supraglottic devices are unclear, but in another recent publication these devices were shown to decrease carotid blood flow in an animal study.25

At the present time, the best way to initially manage an airway in cardiac arrest is unclear. What is clear is that, if ETI is an EMS agency’s initial airway of choice, it is essential that paramedics be truly expert at this skill, practice often, be prepared for difficult airways, perform this skill rapidly with minimal interference to compressing the chest, and don’t hyperventilate patients once they are successfully intubated.

Agencies should carefully consider whether bag-valve ventilation or using an SGA may be more appropriate than requiring ETI to be the preferred airway of choice.

While ALS continues to be part of the AHA/ECC chain of survival, its effect on survival to hospital discharge has come into question. To that end, the 2010 AHA Guidelines de-emphasized IV access and drug delivery. This stance is supported by the lack of evidence demonstrating increase in survival to hospital discharge with administration of vasoactive medications and antiarrhythmics in the field.

There is also concern with the use of epinephrine because it may have deleterious effects on cerebral microcirculation and post-arrest myocardial function. Multiple studies have attempted to address the issue of the role of epinephrine and other ACLS drugs in cardiac arrest and their impact on patient survival.

In 2009, Lars Wik and colleagues randomized patients with out-of-hospital cardiac arrest to ACLS with and without access to IV drug administration.26 Their results demonstrated an increase in ROSC with IV drug administration (40% vs. 25%), but not a statistically different difference in survival to hospital discharge (10.5% vs. 9.2%). Thus they found no long-term benefit to ACLS drugs.

Similar results were recently published in a large study from Japan involving almost 500,000 patients, 15,000 of which received epinephrine.27 Although there was a dramatic improvement of ROSC with epinephrine (18.5% vs. only 5.7% without epinephrine), the one-month survival data was quite different. At one month, those receiving epinephrine fared much worse and were less likely to be alive or alive with good neurologic function (5.1% with epinephrine vs. 7.0% without; and 1.3% vs. 3.1% respectively for good neuro outcomes). These deleterious effects were seen in patients with VF/VT or a nonshockable rhythm.

Atropine’s role in cardiac arrest has also been recently evaluated, and like the epinephrine studies cited above, has yielded very surprising results. The SOS-KANTO Trial studied 7,448 patients to compare the effect of epinephrine plus atropine vs. epinephrine alone in patients with either asystole or PEA.28 Atropine improved ROSC in both rhythms and did not affect the 30-day survival of patients with asystole. However, at 30 days, those patients who received atropine plus epinephrine had decreased survival as compared to those who received epinephrine alone (3.2%
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* 2010 American Heart Association Guidelines for CPR and ECC and ATLS.

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vs. 7.1%), and of the survivors, atropine decreased the likelihood of good neuro survival (0.59% vs. 1.02%).

Other studies have shown similar findings with the use of epinephrine. Similar to adrenaline, there is insufficient data demonstrating improvement in survival to hospital discharge with the use of vasopressin, lidocaine and amiodarone.

It is important to recognize that as post-arrest care improves with the implementation of therapeutic hypothermia and transport to PCI-capable centers, increases in the rate of ROSC with the use of epinephrine and anti-arrhythmics in the field could potentially translate into improvement in survival to hospital discharge. It is clear, however, that a focus on obtaining IV access and administering ACLS medications cannot trump initiation of other lifesaving measures.

ACLS will continue to be part of OOH cardiac arrest resuscitation, however, at this time, given the lack of good evidence demonstrating clear benefit with the routine use of IV medications in the field, services must focus on interventions that have proven efficacy, such as good CPR, early defibrillation and coordinated post-arrest care with transport to resuscitation centers that can provide both therapeutic hypothermia and early cardiac catheterization.

METHODS TO AVOID HYPERVENTILATION & MAXIMIZE COMPRESSIONS

Recent CPR research has focused on developing technology that will assist providers in delivering optimal CPR to ensure the best possible chance of ROSC followed by transport to a resuscitation center able to continue post-arrest care.

The importance of providing more than 80 compressions per minute has been noted in animal studies as well as many clinical observations. In addition, evidence suggests that excessive positive pressure ventilation and hyperventilation during CPR can be detrimental to resuscitation hemodynamics and outcomes in patients suffering from cardiac arrest.

METRONOME USE

Metronomes are relatively inexpensive, are available on some cardiac monitor/defibrillators, and can provide EMTs and paramedics with much-needed feedback to stay on target with compression and ventilation rates.

A 2010 study that looked at the use of an audible metronome for guiding chest compressions rate demonstrated that metronomes are beneficial in improving the rate and effectiveness of chest compressions. (For more information on metronome use in CPR, see p. 8 of this supplement.) A 2009 study found that a combination tock (sound) and voice-prompting metronome was effective at directing correct chest compression and ventilation rates both before and after intubation. For this study, 68 firefighter EMTs from the Spokane (Wash.) Fire Department and Spokane Valley Fire Department participated in pairs, 17 pairs for the intervention (CPR metronome) group and 17 pairs for the control group. Each pair performed two CPR sessions, switching roles between sessions, resulting in 34 CPR sessions for each group.

This was the first study to methodically evaluate metronome guidance of both chest compressions and ventilation, both before and after endotracheal intubation. The combined tone and voice prompt audio guidance was effective at maintaining the target chest compression rate and avoiding the common problem of hyperventilation during CPR by professional rescuers.

Without any audible guidance, chest compressions rates varied widely, from 75–160 per minute. Without metronome guidance, 29 out of 34 (85%) of the professional rescuer pairs performed chest compressions outside the range of 90–110 compressions per minute, and 24 out of 34 (71%) were outside the broader range of 90–120 compressions per minute proposed as a target by Kramer-Johansen et al. Of note, the majority of those compression rates outside the range were above 120 per minute.

Too slow a rate delivers too few compressions per minute to achieve optimal resuscitation haemodynamics and outcomes. At the time of this 2010 study,
it was assumed that too fast a compression rate is less harmful than too slow, but both extremes can be problematic. We now know from the Idris study (see p. 4) that very fast compression rates (greater than 125/minute) can compromise coronary blood flow due to a significant shortening of the diastolic period when the majority of coronary flow occurs.32

In one of the largest studies, Kern et al discovered that without the metronome device, only 15% of pre-hospital providers achieved an appropriate compression and ventilation rate. However, with the utilization of the audible metronome, 100% of the caregivers provided appropriate compressions as well as avoided hyperventilation.53

The need and role for patient ventilation during resuscitation has also been dramatically re-thought during the last decade. Some believe minimal or no positive pressure ventilation should be provided during the early resuscitation efforts.33,54–56 Many believe hyperventilation during resuscitation is particularly harmful.47 Most researchers and clinicians appear to agree that some source of re-oxygenation and ventilation (be it positive pressure techniques or passive oxygen insufflation delivered by a device such as a high concentration oxygen mask and bag, combined with chest compressions) is important sometime in the rescue protocol.

The major issue is how to provide oxygenation and adequate ventilation without the deleterious effect on haemodynamics associated with over-ventilating during the low flow state of CPR.

Hyperventilation is common during in-hospital and out-of-hospital treatment of cardiac arrest. A 2005 study at the University of Chicago Hospitals reported that in a series of 67 patients, the ventilation rate exceeded 20/minute (−1) in 59% of the CPR periods.48

University of Wisconsin investigators studied the number of breaths provided by professional EMS rescuers responding to cardiac arrests in their communities. Remarkably, they found that their professional EMS personnel provided 37±4 breaths/minute, with a range of 19–49 minute (−1).47 Recognizing this as a potentially major problem, extensive re-training was conducted emphasizing the importance of no more than 10–12 breaths/minute. A second period of observation of actual EMS performance was then carried out and revealed an average ventilation rate (after re-training) of 22±3 breaths/minute, with a range of 15–31/minute. No patient in that follow-up period had a ventilation rate (after re-training) of 10±0, median = 10, and none were hyperventilated (0/34).49

MECHANIZING CPR

Whereas the metronome provides a guided means for rescuers to perform manual chest compressions, there is increasing interest in mechanical compression devices that deliver the appropriate and consistent depth, rate and recoil necessary, thus “freeing” responders to perform other critical tasks during the resuscitation. Initial concerns with the use of these mechanical delivery systems were their cost as well as the amount of “time off the chest” while applying the device to the patient.

The early research was quite promising regarding the benefit of these devices. Ong and Ornato et al performed an analysis of more than 700 adults with non-traumatic OHCA and found that compared to manual CPR, a resuscitation strategy using a load-distributing band chest compression device improved survival to hospital discharge.58 Conversely, in the same journal, Hallstrom and Rea performed a multicenter randomized trial of automated compression devices and concluded that patients receiving this therapy suffered worse neurologic outcomes and a trend toward worse survival as compared to manual CPR.59 These competing conclusions on such devices resulted in a dramatic increase in their study and improvement.

As technology advances and more studies are conducted, these devices may pave the way for improved survival with neurologic function post-cardiac arrest. For more information on mechanical CPR, see “The Merits of Mechanical CPR” on p. 24 of this supplement.

THE ITD

The use of an impedance threshold device (ITD), also referred to as the ResQPOD, as a circulatory adjunct during CPR has become more common in the prehospital care of the cardiac arrest victim. The purpose of the ITD is to impede the return of respiratory gases into the chest selectively during the recoil phase of CPR, thus enhancing negative intrathoracic pressure and improving blood pressure and cardiac output. It also contains timing assist lights, which may be turned on to provide guidance on proper chest compression and ventilation rates.60

Pirallo et al initially studied this device and found that as compared to a “sham” device, the ITD was safe and improved blood pressure in arrest victims.61 This promising study led to further investigation into the use of the ITD as a standard adjunct to traditional CPR and some believe that this device may dramatically increase sur-
vival from OHCA.

However, a very large trial (ROC PRIMED) which further analyzed the ITD was conducted at 10 locations across the U.S. and Canada and involved more than 20,000 EMS providers. Unfortunately, the Data and Safety Monitoring Board recommended that the study end enrollment and terminate early because the ITD use was showing no improvement in patient survival rates (it did not show a decrease in survival rate).62

Despite the results of this one study, many EMS systems have used, and continue to use, the ITD along with other important resuscitation components and are experiencing increased resuscitation results.

A 2009 observational time series study in Wake County, N.C., involved 1,365 patients and measured survival to hospital discharge in patients with OHCA during a tiered implementation of the 2005 AHA Guidelines. This urban/suburban EMS system, which responded to 65,000 calls, including 700 cardiac arrests at the time of the study, was able to double survival between the pre- and post-implementation phases by implementation of a community-wide focus on resuscitation and the sequential implementation of 2005 AHA Guidelines for compressions, ventilations and induced hypothermia.

The 46-month study focused on results of using dispatcher-assisted CPR instructions (MPDS), dispatch of ALS units, a fire department first-responder apparatus and a paramedic supervisor vehicle for presumed cardiac arrests; automated defibrillators reprogrammed to deliver a single shock that delivered the highest energy level available for each shock rather than a “stacked” sequence (up to three shocks); paramedic crews manually delivering a “stacked” sequence of up to three shocks without interposed chest compressions; minimal interruption of chest compressions; use of intraosseous infusion (EZ-IO), therapeutic hypothermia and the ResQPOD ITD; control of ventilation rates guided by a timing light on the ResQPOD; and the concept of working cardiac arrests in the field until ROSC or obvious futility.63 Note: For an additional study, “Intraosseous Infusion Proven Effective in Therapeutic Hypothermia,” sponsored by Vidacare, go to www.jems.com/article/patient-care/io-in-th-web-bonus.

Aufderheide et al compared the use of an ITD with Active Compression Decompression CPR (ACD-CPR) in the ResQTRIAL. This was a multicenter, prospective, randomized, prehospital clinical trial that compared an ITD (ResQPOD) and ACD-CPR Device (ResQPUMP) to conventional CPR in more than 1,600 patients.64

For patients with cardiac etiologies, the combination of ACD-CPR with an ITD resulted in a 53% increase (5.8% to 8.9%) in survival to hospital discharge with favorable neurologic function and a survival benefit of 49% persisted to one year. This study builds on 22 animal and four human trials previously demonstrating positive hemodynamic and survival benefits when ACD-CPR is combined with an ITD.

TRANSPORTATION OF PATIENTS WITH ROSC TO RESUSCITATION CENTERS

Post-arrest cardiac care was one of the most notable sections of the 2010 AHA Guidelines. The guidelines note that organized post-arrest care with an emphasis on multidisciplinary programs that focus on optimizing hemodynamic, neurologic and metabolic function (including therapeutic hypothermia) may improve survival to hospital discharge among victims who achieve ROSC following cardiac arrest either in- or out-of-hospital.

Although it is not yet possible to determine the individual effect of many of these therapies, when bundled as an integrated system of care, their deployment appears to improve outcomes.65 This is a strong statement that lends support for standard EMS protocols that deem that post-cardiac arrest patients who have successfully received ROSC in the field be transported to a center capable of providing intensive post-resuscitative care (angiography and hypothermia) despite bypassing a closer facility. Recent evidence firmly establishes that hospitals that do provide early coronary angiography as well as controlled hypothermia can improve patient sur-
Hands Down
Nobody Beats ZOLL When it Comes to CPR

CPR quality is crucial. In systems that have focused on improving CPR quality, both in and out of the hospital, survival rates from sudden cardiac arrest have doubled, or even tripled.1,2

When it comes to assisting rescuers in providing the best CPR possible, no one is more experienced or can offer you as much as ZOLL.

Real CPR Help® — Guides rescuers to proper depth and rate of compressions with real-time audio and visual feedback.

See-Thru CPR® — Reduces the duration of pauses during CPR by filtering CPR artifact so rescuers can see the underlying rhythm.

CPR Dashboard™ — Displays depth and rate of compressions and assists rescuers in achieving full compression release with guidance from a prompt and a release indicator.

Learn more about the newest AHA guidelines, and how ZOLL technology can help you improve CPR quality at www.zoll.com/medical-technology/cpr/guidelines-2010.
vival and neurologic outcomes, specifically if the initial rhythm is VF.

In Seattle, researchers retrospectively studied 491 consecutive adult patients with out-of-hospital, non-traumatic cardiac arrest who presented before and after a protocol for hypothermia was instituted. These patients all had ROSC and various initial rhythms (asystole, PEA, VF/VT). The researchers concluded that a ventricular fibrillation arrest victim who was then cooled after ROSC had an almost two-fold increase in neurologically intact discharge from the hospital. This did not hold true for other presenting arrhythmias.

Similar results were found in an Australian study of more than 100 cardiac arrest victims where therapeutic hypothermia and early coronary angiography dramatically improved neurologically intact survival to hospital discharge (64% vs. 39%).

Given such statistics as these, the U.S. Metropolitan Municipalities EMS Medical Directors ("Eagles") Consortium endorsed transportation of patients to resuscitation centers, noting that it is not feasible for many hospitals to make the commitment to care for large numbers of critically ill patients and the accompanying investigational activities, whether in the prehospital, ED or inpatient arenas.

CONCLUSION

While much has been done, and continues to be accomplished in the area of patient resuscitation, we must continue to research, innovate and implement processes and procedures to improve our resuscitation of patients. The old "mold" and methods may need to be replaced by new protocols, equipment, staffing and response models and transportation (and non-transport) of patients.

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REFERENCES


Q&A with Joan Mellor

Program manager, Medtronic Foundation’s HeartRescue Project

The Medtronic Foundation’s Joan Mellor oversees the Foundation’s HeartRescue Project, a collaborative initiative designed to improve how SCA is recognized, treated and measured in the U.S. Most importantly, it’s an ambitious effort to change the way we collectively respond to sudden cardiac arrest (SCA). Partners involved in the project are working to improve SCA survival rates by 50% over five years by implementing measurable, evidence-based best practices among citizen bystanders, prehospital responders such as police, fire and EMS, and hospitals.

Despite years of working to reduce the high death rate from SCA, Mellor has high hopes that the rates can be significantly improved. “It’s been such a tough disease to tackle, and nobody has been able to do it in a way that is really scalable,” she says. “And yet several communities across the country, including places like Arizona and Seattle-King County in Washington, have proven that increasing survival rates is possible.”

Mellor was pleased to participate in this special editorial supplement to JEMS and speak about the HeartRescue Project and what she thinks it will take to achieve a reduction in SCA deaths on a national scale.

Q: What is the HeartRescue Project?
A: The HeartRescue Project is an initiative designed to improve survival from SCA in the U.S. Remarkably, even though nearly 400,000 people die annually from SCA, and U.S. survival rates are between 8–10%, this survival rate hasn’t changed in 30 years, except in a few pockets of communities that have significantly higher survival rates than the national average.

In 2010, the Medtronic Foundation made the decision to recruit and work directly with partners known for their leadership in resuscitation, who in turn would coordinate activities to definitively improve survival in their respective geographies. The current partners include leading universities in six states and American Medical Response, which responds to 25,000 SCAs annually in 2,000 communities throughout the U.S.

These partners have accepted a common challenge to improve cardiac arrest survival by 50% over five years in their geographic service areas. Each partner is being asked to develop and expand SCA response systems by coordinating measurement, education, training and the application of evidence-based best practices among the general public, first responders, EMS and hospitals. They’re also being asked to connect bystander, prehospital and hospital response by applying published science to strengthen the chain of survival.

Every step in the chain of survival counts. There is bystander response, which includes early recognition of SCA, early initiation of bystander CPR and easy access to AEDs. There’s prehospital response, including dispatchers who can recognize SCA and quickly get someone to start chest compressions. That alone is a huge opportunity to improve SCA survival rates. Then we need the EMS team to perform high-quality CPR, to provide defibrillation care and then early advanced care.

Finally, when patients are transported, is the hospital ready for them? Is that person getting triaged to a resuscitation center of excellence? Is there in-hospital hypothermia? Is there 24/7 access to a cath lab? Is the patient receiving post-surgery treatments appropriate for their underlying condition? And are the patients and families receiving education and support to manage their disease?

Q: Why are measurement and data so important to this initiative?
A: We can’t improve what we don’t measure. And SCA is not currently a reportable condition in this country. So a core element of the HeartRescue Project is to measure cardiac arrest performance and outcomes.

Our partners are committed to helping define a data dictionary to make sure we’re measuring things consistently. They are also working with the EMS agencies, hospitals and other agencies to not only get outcomes data through electronic patient care reports, but to add elements from the dictionary to their patient care reports so we are getting key information that helps us improve survival.

The information being collected is comprehensive but not overly burdensome in terms of data elements requested for each case of SCA. Some of the key ques-
tions include:
• Did a bystander start CPR?
• Was an AED used? If so, by whom?
• Did the patient arrive alive at the hospital?
• Did they receive hypothermia?
• Did they receive appropriate post-resuscitative care?
• Did they get discharged alive?

The goal is to measure the continuum of care for patients who have suffered cardiac arrest. Then we have to make sure that data gets back to the EMS and hospital providers so they can use it to improve what they’re doing.

All data collected at the state level is then put into the Cardiac Arrest Registry to Enhance Survival (CARES) surveillance registry.

Q What makes the HeartRescue Project different from other efforts to improve SCA survival?

A Some of the core features of the HeartRescue Project are that we have publicly stated measurable goals, we focus on data collection and it’s highly collaborative. We’re bringing together hundreds of stakeholders in each state with a focus on one goal, which is reducing deaths from SCA.

At the outset of the project we wanted to work with leaders in resuscitation who could help us replicate the great work they were already doing, typically at the community level, but then spreading it across the state. Through their leadership, they’re creating teams of bystanders, as well as EMS and in-hospital providers, to work together so it becomes a collective project that has collective impact. This is different from an individual community taking this on. We’re asking our partners to be a hub for a state, to partner with and collaborate with other agencies and organizations.

The reality is that we haven’t been able to improve survival in 30 years on a broad-based scale. So how are we going to do it today? We believe there has to be partnerships built between the bystander, prehospital and hospital response levels. Working together on implementing best practices and measuring progress will make the difference.

Q Are SCA survival rates an indicator of overall EMS system effectiveness?

A I believe they are. If you improve your ability to treat SCA—what some consider the most serious, time-sensitive problem that exists at the acute care level—then it stands to reason it’s going to improve your entire EMS system. Sometimes EMS providers will say, “We can’t focus this much time and energy on 1% of our calls.” But if you can tackle the toughest cases, you are likely going to be improving care for all your patients.

When you address cardiac arrest, you’re also creating a network of care that you can now apply to other diseases. For example, in areas that have a ST-segment elevation myocardial infarction (STEMI) network, they already have great relationships between prehospital providers and hospitals. So it’s much easier to dovetail resuscitation efforts into that, and vice versa.

Take the case of Arizona, for example. They’ve created a wonderful statewide SCA system of care. Now they’re applying this network of collaboration and relationships to traumatic brain injury with great success. We’re starting to see stroke, STEMI, cardiac arrest and even trauma and traumatic brain injury connecting with one another into larger acute care systems.

Some people think it’s a lost cause, that SCA isn’t treatable. But we know, through the experience of our partners, that it is. We need to instill that in the consciousness of our prehospital and hospital systems, as well as in the minds of the general public. We need to believe we can make a difference. Our partners are charged with creating more believers through proof of success.

Q Are there any success stories yet?

A The success stories right now are foundational. All the states that are involved are working toward developing a network of EMS providers and hospitals that agree to collect the same data and are starting to put the data into the system. That’s huge. In just a year and a half, all five of our original partner states are covering at least 50% of their population in terms of out-
comes data collection.

The other success so far is that communities around each state are embracing the concept and starting to work together at each level of response and as whole teams across geographies. The Resuscitation Academies are a huge success. They started in Seattle several years ago and are now offered through partner collaborations by every HeartRescue partner. They were initially intended to educate EMS medical directors about best practices for resuscitation; now there are Resuscitation Academies for dispatchers to learn about best practices in dispatch-assisted CPR, for EMS providers to learn high-performance CPR and for hospital staff to teach post-resuscitative care, including in-hospital hypothermia. Measurement is one piece. Education and sharing of best practices among the sites is the other.

**Q** How important is bystander CPR to improving survival?

**A** We can’t improve survival without bystanders. The chances of survival double if a bystander provides timely CPR. Bystanders also need to call 9-1-1 and ask for an automated external defibrillator (AED). None of this works without the bystander.

All of the partners are taking on bystander CPR in a way that fits for that state. For example, in Arizona, they’ve done public awareness campaigns through the Department of Health to increase hands-only CPR. Their next step is to improve dispatcher-assisted CPR, which means training dispatchers in recognizing cardiac arrest and instructing bystanders to start CPR as quickly as possible.

Other states are focusing on the Internet and social media. In Philadelphia, they’ve run a contest in which citizens were asked to locate and snap pictures of AEDs. They do a good job of training their dispatchers: Dispatchers know how to recognize it, give clear instructions and give the bystander enough confidence to try it. The American Heart Association has released recommendations for dispatcher-assisted CPR. There are basically two questions: the dispatcher should ask if the person is responsive and if they are breathing normally. If the answer is “no” to both questions, the bystander should be directed to start chest compressions. However, some dispatch organizations may use dispatch software that includes more than these two questions. No matter what protocol is used, a quality assurance process for reviewing cardiac arrest calls is recommended to minimize the time between 9-1-1 call and first compressions and ultimately save more lives.

**Q** Why is it important to hold Survivor Summits?

**A** Survivor Summits are important because SCA doesn’t have pink ribbons or three-day walks; there is no such voice for this problem. Of course I support breast cancer and other types of research, but 40,000 people in the U.S. die annually of breast cancer, while 400,000 die of out-of-hospital cardiac arrest. We need to continue to build a patient community of people who have been affected by SCA so they can support one another and become the voice that affects policy and healthcare decisions about treating this disease so more people survive.

If you think of other diseases, such as cystic fibrosis or pediatric leukemia, these are diseases that didn’t have long-term survival rates in the ’60s and ’70s. But as better care progressed and more patients survived, they started creating support groups and registries and organizing as patient communities to advocate for continued research and funding.

We’re now starting to see this gradually build among survivors of SCA, with groups like the Sudden Cardiac Arrest Association and the Sudden Cardiac Arrest Foundation. Survivors are powerful advocates, and the more we can support their efforts to organize and strengthen their national presence, the better.


Jennifer Goodwin is associate editor of the monthly newsletter Best Practices in Emergency Services.
“Thanks to a strong game plan, I’m alive today.”

Dale Wakasugi, Minnesota High School Basketball Referee and SCA survivor

Saving lives requires a well-coordinated team effort, bringing together members of the public, EMS and hospitals. That’s why the Medtronic Foundation launched the HeartRescue Project, an unprecedented collaborative effort to reduce SCA deaths in the United States. Together, we’re working toward a day when survival stories like Dale’s are the norm, not the exception.

Download a copy of the SCA Response Planning Guide at HeartRescueProject.com

Test your life-saving skills with this interactive tool, visit heartrescuenow.com.
The Merits of Mechanical CPR

Do mechanical devices improve compression consistency and resuscitation outcomes?

Approximately 460,000 individuals die every year from out-of-hospital cardiac arrest (OHCA). Studies have consistently shown only an average of 5–15% of patients treated with standard CPR survive cardiac arrest, and providing optimal blood flow to a patient in cardiac arrest by performing quality, uninterrupted CPR is uniformly thought to have a positive impact on improving overall survival.

The quality of CPR has been an underappreciated factor and is only now beginning to emerge as an important aspect of successful resuscitation. Manual chest compressions are often done incorrectly, especially in the back of a moving ambulance, and incorrect chest compression can negatively impact survival.

Fortunately, there are tools that hold promise for helping providers overcome these inaccuracies: mechanical CPR devices.

THE PROBLEM WITH MANUAL CPR

The quality of CPR is an important factor that contributes to survival in sudden cardiac arrest. In one experimental study, pigs received 4 minutes of VF and then 9 minutes of CPR before defibrillation. In the group that received suboptimal compressions (1.5 inches depth and 80 per minute), two out of nine pigs survived; in the group that received optimal compressions (2 inches depth and 100 per minute), eight of nine pigs survived.

The study of adult patients from the Resuscitation...
Outcomes Consortium Cardiac Arrest Epistry with confirmed ventricular fibrillation (VF) or ventricular tachycardia (VT) has shown that increasing chest compression fraction (hands-on time) during out-of-hospital resuscitation of patients with VF/VT is an independent determinant of survival to hospital discharge. However, three human observational studies showed that interruptions of chest compressions were common, averaging 24% to 57% of the total arrest time.

Interrupting CPR can result in precious seconds lost in trying to “reprime” the pump and results in pooling of blood in the right ventricle. In a study looking at this important element of the pathophysiology of cardiac arrest, VF was induced in air-ventilated pigs, after which ventilation was withdrawn. During the first 3 minutes of VF, arterial blood was transported to the venous circulation, with the consequence that the left ventricle emptied and the right ventricle became greatly distended.

It took 2 minutes of mechanical CPR to re-establish an adequate coronary perfusion pressure, which was lost when interrupted. In this pig model, VF caused venous congestion, an empty left heart, and a greatly distended right heart within 3 minutes. Adequate heart massage before and during defibrillation greatly improved the likelihood of return of spontaneous circulation (ROSC).

It is widely accepted that one of the best predictors of ROSC is attaining a coronary perfusion pressure (CPP) of more than 15 mmHg in animals and humans. Every interruption of CPR causes the CPP to drop immediately. In the same pig study referenced above, when VF was induced, CPP fell from 60 mmHg to 15 mmHg in 15 seconds and continued to plummet into negative numbers. After CPR was restarted, the CPP remained negative for the first minute; it took 90 seconds for it to get back up to 15 mmHg.

Another pig study demonstrated that mean CPP was 20 mmHg in the mechanical group compared to around 5 mmHg in the manual group. All eight pigs in the mechanical group achieved ROSC, as compared with just three pigs in the manual group.

With manual CPR, many factors come into play, including fatigue, physical abilities, focus on several simultaneous tasks, poor-quality CPR during transportation on a stretcher and in the back of a transport vehicle, interruptions during movement of patient and variations in technique and training.

Just maintaining the proper rate is a major challenge. In one study, it was demonstrated that manual CPR resulted in a rate of less than 80 compressions/minute 37% of the time. Other studies looked at the challenges in performing correct CPR in various settings. They found the following percentages of correctly performed CPR:

- 54–78% on the floor;
- 46% in the back of a moving ambulance; and
- 21% while transporting on a stretcher.

Besides the poor-quality CPR that occurs in the back of a moving ambulance, the risk of injury to the crew members is unacceptable. It has been reported that ambulance personnel who perform CPR in a moving ambulance are at least four times more likely to have a fatal or incapacitating injury than personnel who are unrestrained.

Mechanical CPR allows high-quality CPR to be performed while EMS personnel are restrained; this reduces risk of injury to the crew. Restrained ambulance occupants involved in a crash have been shown to have 3.77 times lower risk of fatal- and 6.49 times lower risk of incapacitating injury than unrestrained occupants.

**The interruptions in manual CPR increased from 19% on the scene to 27% during transport, whereas those with the mechanical CPR device stayed at the same low ratio (8–10%) both on scene and during transport.**

**CONSISTENT-QUALITY CPR**

The use of automatic mechanical CPR devices can provide a consistent rate and depth of compression and is one way of improving the quality of chest compression and contributing to EMS personnel safety.

There is compelling physiological and animal data suggesting that mechanical chest-compression devices are more effective than manual CPR. At best, standard manual CPR produces coronary and cerebral perfusion that is just 30% of normal.

Some studies that demonstrate the advantages of mechanical CPR devices include:

- Increased brain flow by as much as 60% vs. manual measured in pigs.
- Adequate heart pressures—exceeding 15 mmHg in pigs and humans—significantly improved over manual CPR.
- Increased EtCO2 levels in prehospital cluster randomized patients.
- Increased hands-on times to up to 90% of the time—significantly improved over manual.

A study from Kramer-Johansen et al states, “The poorer results with sinusoidal than trapezoidal chest compressions add to the arguments that mechanical chest compressions can ensure better quality CPR for more than short intervals of time, unless the logistics around applying a mechanical device has too many negative effects.”

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Another advantage of mechanical CPR: it can allow for defibrillation during compressions. In a study on the LUCAS device, it showed that defibrillations did not compromise CPR and can be delivered during ongoing mechanical compressions without any pauses.32

These devices are also helpful in maintaining perfusion during cardiac arrest while undergoing a cardiac catheterization interventional procedure. The AHA 2010 Guidelines (Part 12: Cardiac Arrest in Special Situations) state: “Mechanical chest compression devices have been used successfully in an animal model and adult humans to provide maintenance of circulation in cardiac arrest while continuing a percutaneous coronary procedure. It is reasonable to use mechanical CPR during PCI (Class IIa, LOE C).”33

MECHANICAL CPR CONCERNS
Mechanical CPR is a recent development and as such, the literature around its effect on outcomes is still evolving. Not everyone is a fan of mechanical CPR. A recent systematic literature review of mechanical CPR devices compared to manual CPR during OHCA and ambulance transport concluded that there was insufficient evidence to support or refute the use of mechanical CPR devices in these settings. The study also said that while there was some low-quality evidence suggesting that mechanical CPR can improve consistency and reduce interruptions in chest compressions, there is no evidence that mechanical CPR devices improve survival and may worsen neurological outcome.34

One area of concern with mechanical CPR devices has been the time off the chest while applying the device. However, in our experience with the LUCAS device in Columbus, Ohio, we have found that application takes only 15–60 seconds and that the time off the chest is minimal. In addition, it is important to take into account the total time on and off the chest. In a prehospital real-use study, the hands-off ratio with manual CPR was on average 22%; however, with mechanical CPR it was just 9%, as measured over the entire resuscitation episodes of approximately 33–40 minutes.

The interruptions in manual CPR increased from 19% on the scene to 27% during transport, whereas those with the mechanical CPR device stayed at the same low ratio (8–10%) both on scene and during transport.34

Another more practical concern is the cost of these devices. They can cost nearly the same as a monitor/defibrillator, a cost that many feel is too high for a mechanical device that is not as technology-packed as a cardiac monitor. In addition, one unit sold in the U.S., the ZOLL AutoPulse, has a one-time use band that must be replaced after each use; and this replacement cost is not currently reimbursed by most insurance agencies.

For a demonstration by Cyprus Creek (Texas) EMS
on how a team approach to mechanical compression devices can expedite the application of a device and minimize interruption of compressions, go to http://youtu.be/vlDjk3FA3sU or scan the QR code.

TYPES OF MECHANICAL CPR DEVICES
There are several types of mechanical CPR devices.

Piston CPR Devices
Piston compression devices use battery power (e.g., the LUCAS 2 from Physio-Control) or pneumatic power derived from compressed oxygen (e.g., the LifeStat from Michigan Instruments, which also features an associated integrated ventilator). Early studies found that mechanical piston CPR improved hemodynamic parameters, but not survival.35–38 However, these studies were performed prior to the latest AHA guidelines and before crews began using compressions-only CPR, early adult IO (EZ-IO) establishment, impedance threshold devices (ResQPOD), therapeutic hypothermia and a “pit crew” approach to resuscitation.

Piston chest compression devices have been shown to be actually less damaging than manual CPR.39,40 Trauma, such as rib fractures, is an occasional occurrence in CPR and a complication of this and other mechanical devices.

The 2010 AHA Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science state, “There is insufficient evidence to support or refute the routine use of mechanical piston devices in the treatment of cardiac arrest. Mechanical piston devices may be considered for use by properly trained personnel in specific settings for the treatment of adult cardiac arrest in circumstances (e.g., during diagnostic and interventional procedures) that make manual resuscitation difficult (Class IIb, LOE C).”41 However, EMS insiders believe that the positive results being realized by EMS systems using mechanical CPR devices applied early and efficiently; the move to compression-only CPR and its proven efficacy; and the results of Dr. Idris’ study (see p. 4 of this supplement), which shows the need to keep compressions within a defined range of 100–120 compressions per minute, will result in a stronger position for mechanical CPR in the future.

Active Compression-Decompression (ACD) Devices
This piston technique, not yet approved for use in the U.S., integrates a suction cup that allows for active return of the chest and provides both active chest compression...
and active chest decompression (ACD-CPR).

A 2005 study demonstrated that incomplete chest recoil during CPR worsens hemodynamics. The study, although performed in piglets, indicated that leaning on the chest during CPR and not allowing the chest to fully expand on the upstroke led to worse systolic blood pressure, worse coronary perfusion pressure and substantially reduced myocardial blood flow.

Load-Distributing Band (LDB)
The ZOLL AutoPulse device uses a load-distributing band that is placed around the patient’s chest and circumferentially tightens and loosens around the patient, distributing the force evenly to generate changes in intrathoracic pressure.

Initial studies of the device had found improved hemodynamic parameters and coronary perfusion pressures as well as improved prehospital survival to the emergency department. Recent trials showed improved hemodynamics, with coronary perfusion pressures above the level generally associated with improved survival, as well as improvement in survival to arrival at the emergency department when compared with manual CPR.

A multi-site cluster-randomized trial (ASPIRE) that the Columbus (Ohio) Division of Fire participated in was terminated early due to a lack of benefit and apparent harm. It is believed that site-specific factors had led to the poorer results, and further clinical research is still ongoing.

However, in the 2006 JAMA article, the authors looked at 783 adults with non-traumatic cardiac arrest in the prehospital setting. They compared resuscitation outcomes before and after switching over their urban EMS system to a load-distributing band (LDB) CPR device. They compared 499 patients in the manual CPR phase and 284 patients in the LDB CPR phase. The LDB device was placed on 210 out of the 284 patients in this last phase.

Rates for ROSC and survival were increased with LDB CPR compared with manual CPR. Survival to hospital admission was 20.9% in the LDB CPR group vs. 11.1% in the manual CPR group, and survival to hospital discharge was 9.7% vs 2.9% respectively.

In secondary analysis of the 210 patients on whom the LDB device was applied, 38 patients (18.1%) survived to hospital admission (95% CI, 13.4%–23.9%) and 12 patients (5.7%) survived to hospital discharge (95% CI, 3.0%–9.3%). Among patients in the manual CPR and LDB CPR groups who survived to hospital discharge, there was no significant difference between groups in cerebral performance category (P=.36) or overall performance category (P=.40).

Their final conclusion: Compared with resuscitation using manual CPR, a resuscitation strategy using LDB CPR on EMS ambulances is associated with improved survival to hospital discharge in adults with out-of-hospital nontraumatic cardiac arrest.

According to the 2010 AHA Guidelines, “The LDB may be considered for use by properly trained person-
nel in specific settings for the treatment of cardiac arrest (Class IIb, LOE B). However, there is insufficient evidence to support the routine use of the LDB in the treatment of cardiac arrest.41

THE COLUMBUS EXPERIENCE

The Columbus (Ohio) Division of Fire has had the opportunity to use and evaluate several types of mechanical CPR devices. We used the Thumper devices in the 1970s and 1980s, and we were one of the participating systems in the ASPIRE trial, which provided exposure to the Auto-pulse device.

In July 2011, we put LUCAS devices on three of our EMS officer vehicles. In the first six months of usage, we used the devices 71 times. Although this was not a scientific study, our average ROSC rate with manual CPR was 30.5% and our hospital discharge rate was just 11.1%. With the LUCAS device it was 19% and 2.3%.

During the first six months of 2012, the ROSC rate and hospital discharge rate with manual CPR was 33% and 12% respectively and with the LUCAS it was 30% and 4%.

Our results are not as positive as some other systems that have mechanical CPR devices on all of their ALS vehicles because the LUCAS devices were only available on our EMS officer vehicles. Although manual CPR had been going on from the start of each arrest, the device was being applied late into most cardiac arrests. It was also being applied to patients who had not quickly converted from a ventricular fibrillation or ventricular tachycardia rhythm.

The Columbus Department of Fire EMS staff has a favorable attitude about mechanical CPR devices. The advantages in terms of job enhancement have already been discussed. In a survey we conducted, our EMS personnel reported the following:

- 60% of providers surveyed said application time for the LUCAS device was less than 30 seconds; 40% said it was 30–60 seconds.
- 100% of providers surveyed said the LUCAS 2 device makes the treatment of cardiac arrest patients in the field go smoother than with manual CPR.
- 100% of providers surveyed said they obtained ROSC (pulses) more often on patients that have the LUCAS device applied than with manual CPR.
- 100% of providers surveyed said they see no drawbacks to using mechanical CPR in the field.
- Responders identified the following advantages to using the LUCAS device in the field: It gives them more time to focus on other skills and patient care; it is safer for transport in the back of the medic (no one standing to perform CPR); it can be applied rapidly and, once applied, provides consistent CPR with no interruptions.

SUMMARY

In the Cochrane review, a large literature review of randomized controlled trials (RCTs), cluster RCTs and quasi-randomized studies that compared mechanical chest compressions to manual chest compressions, the authors conclude: “There is insufficient evidence from human RCTs to conclude that mechanical chest compressions during cardiopulmonary resuscitation for cardiac arrest are associated with benefit or harm. Widespread use of mechanical devices for chest compressions during cardiac arrest is not supported by this review. More RCTs that measure and account for CPR process in both arms are needed to clarify the potential benefit from this intervention.”50

Further studies are needed to truly determine the efficacy of mechanical CPR devices. The LINC study, a large RCT comparing LUCAS to manual CPR, is ongoing and expected to complete enrollment in the next few months. The LINC trial is a prospective randomized multicenter study where LUCAS will be used with simultaneous defibrillation compared to manual chest compressions. The study is being conducted in first-tier systems, where LUCAS always will be placed in the first-arriving ambulance.

There also has been promising research showing benefit of Active Compression Decompression CPR and it is expected that the LUCAS device and others will utilize this method of CPR in the future. Studies with these devices will also be critical in assessing the overall survival of patients receiving combined mechanical and ACD CPR.
REFERENCES


Depth Perception

Application provides feedback on compression depth

The importance of quality CPR for victims of cardiac arrest is beyond question. Real-time guidance and feedback on chest compression rates is already helping EMS teams perform better CPR. Now, more accurate feedback for chest compression depth is on the horizon, with a new application in development by Physio-Control.

Compression depth is one of the main determinants of coronary perfusion pressure, which in turn is a primary predictor of patient survival. To adequately circulate a patient’s blood, rescuers must push hard enough—at least 2 inches for adults, according to the 2010 American Heart Association (AHA) Guidelines.

Devices on the market today use a single accelerometer to provide feedback on chest compression depth, which can be misleading if CPR is performed on patients on a soft surface such as thick rug with padding underneath, in a moving vehicle or on a hospital gurney with a flexible mattress—even if the patient is on a backboard or other rigid device.

“Recent studies and the AHA guidelines2-5 say today’s compression depth feedback devices have questionable accuracy on soft surfaces like a mattress or stretcher. That’s because accelerometer-based CPR feedback devices cannot distinguish between compression of the chest and deflection of the underlying surface, like a mattress,” explains Isabelle Banville, PhD, principal scientist for Physio-Control. “We looked at all this and asked, how do we provide better accuracy? That’s why we developed the triaxial field induction technology.”

Triaxial field induction (TFI) technology measures changes in the strength of a very low-energy 3D magnetic field generated by a reference pad placed beneath the patient. A sensor on the patient’s chest continuously detects the 3D magnetic field and calculates the changing distance to the reference pad as the rescuer performs compressions on the patient’s chest.

“It measures the relative distance from the chest sensor to reference pad, regardless of patient movement—such as a moving ambulance or the flexing of a mattress,” Banville explains. During a resuscitation attempt, TFI allows accurate compression depth target to be displayed so the caregiver knows to push harder if needed.

“At any time during CPR, with TFI technology, you know how effective you are at providing CPR. You know how deep you have compressed the chest on a patient,” Banville says. She expects the accurate real-time feedback to significantly improve EMS performance to the AHA guidelines.

“Just as important,” says Banville, “is the fact that more accurate compression depth measurements also mean that quality data will be used to assess current protocols and lead the way to future guidelines.”

The vagueness of current AHA guidelines (“at least 2 inches”) provides no concrete assistance to adequate performance and leaves medics in the field to estimate compression depth based on pediatric patient size (such as one-third the diameter of the chest). Capturing and analyzing accurate data could lead to more specific, evidence-based guidelines.

Today, EMS agencies use Physio-Control’s CODE-STAT 9.0 data review software in their post-event review efforts to improve performance and target training. Banville envisions that in addition to assessing compression rates and compression fractions, they will also use compression depth data.

Kathleen Klein is a medical writer with 25 years’ experience on topics ranging from cardiac resuscitation to neonatal medicine. Based in Seattle, she has worked for the University of Washington Health Sciences Center, Group Health Cooperative and onHealth.com.

REFERENCES
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