

PROCEEDINGS FROM THE 2ND ANNUAL INTERNATIONAL

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**FUTURE** OF  
**RESUSCITATION**  
CONFERENCE



October 14-15, 2019 — Parc Floral, Paris, France

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1. Edelson et al. Interim Guidance for Basic and Advanced Life Support in Adults, Children, and Neonates With Suspected or Confirmed COVID-19: *Circulation* 2020 (<https://www.ahajournals.org/doi/10.1161/CIRCULATIONAHA.120.047463>).
2. Matos RI et al. DoD COVID-19 Practice Management Guide; Clinical Management of COVID-19. [https://www.usuhs.edu/sites/default/files/media/vpe/pdf/dod\\_covid-19\\_pmg14may20acc.pdf](https://www.usuhs.edu/sites/default/files/media/vpe/pdf/dod_covid-19_pmg14may20acc.pdf)

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Stryker Canada  
2 Medicorum Place  
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Proceedings from the 2nd Annual International

# State of the Future of Resuscitation Conference

October 14-15, 2019  
Parc Floral, Paris, France

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**EDITOR-IN-CHIEF** A.J. Heightman, MPA, EMT-P  
**MANAGING EDITOR** Ryan Kelley, NREMT  
**DESIGN & LAYOUT** Kermit Mulkins



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# INTRODUCTION

by Keith Lurie, MD; Lionel Lamhaut MD, PhD; Charles Lick MD & A.J. Heightman, MPA, EMT-P

**I**n October 2019, 30 resuscitation experts presented important work, advancements and successful outcomes at the 2nd Annual International State of the Future of Resuscitation Conference in Paris, France. The attendees were told that the faculty believes we are at the “dawn of the resuscitation revolution,” with both science and technology intertwined

and meshing to allow new and more advanced resuscitative practices.

The conference focused on all aspects of resuscitation and EMS systems worldwide that studied out-of-hospital cardiac arrest survival rates before and after implementation of special practices and procedures designed to improve resuscitation outcomes.

The conference was co-organized by SAUV life and Take Heart America: A Sudden Cardiac Arrest Initiative. The meeting was co-sponsored by the French, Dutch, Spanish, and European Resuscitation Councils; Take Heart America; the Metropolitan EMS Medical Directors (aka “the Eagles”); the Minnesota Resuscitation



**Conference faculty agreed on advances in CPR delivery techniques and technology that facilitate optimal resuscitation care.**

Collaborative; and the Alameda County California EMS System.

### **INCREASING SURVIVAL RATES**

The focus of the conference was on a “Bundle of Care” approach to the treatment of cardiac arrest.

The bundle of care approach helps ensure a systematic and carefully performed choreography of interventions and care both at cardiac arrest scenes and after resuscitation. This approach has so far been associated with as much as a doubling in survival rates from out-of-hospital cardiac arrest.<sup>1</sup>

The conference faculty agreed that optimal resuscitation care can occur when the following are in place:

1. Dispatcher-assisted CPR and/or smartphone app-assisted community response programs to help recognize signs of life, such as gasping, and to ensure compressions are started before EMS arrival;
2. Widespread AED availability and CPR skills training in schools and businesses;

3. Retraining of all EMS personnel in evidence-based and proven methods to enhance circulation, including high-quality manual CPR to minimize CPR interruptions and compression at the correct rate and depth that allows for full chest recoil, performing CPR before and after single-shock defibrillation, and use of mechanical CPR and circulatory adjuncts including active compression/decompression CPR, use of an impedance threshold device, device-assisted elevation of the head and thorax, and extracorporeal membrane oxygenation (ECMO);
4. Protocols for transport to, and treatment by, cardiac arrest centers for therapeutic hypothermia, ECMO, coronary artery evaluation and treatment, and electrophysiological evaluation. New and promising innovations presented at the conference that should be considered in an optimal bundle of cardiac arrest care included:
  - Advances in ultrafast cooling by total liquid ventilation;
  - Device-guided head-up/torso-up CPR with active compression/decompression devices (ACD CPR);
  - EtCO<sub>2</sub> and cerebral oximetry monitoring;
  - Appropriate use of mechanical CPR devices;
  - ECMO;
  - Neuroprognostication;
  - Pharmacology for post-arrest care; and
  - Delivery of AEDs by drone in advance of formal EMS responders.

Additional advances that were highlighted included:

- New data identifying optimal combinations of compression rate and depth;
- Use of smartphone apps for identifying and locating cardiac arrest patients, as well as deploying and using citizens as an extension of the EMS system;
- Use of REBOA in the ED as well as in the field; and
- Use of cadavers and animal models to learn from and improve resuscitation. (An animal study was performed at the conference demonstrating to attendees the clinical value of many of the new technologies listed above.)

This report gleans highlights from many of the important lecture reports, findings and recommendations for resuscitation practices that were presented at the conference.

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1. Lick CJ, Aufderheide TP, Niskanen RA, et al. Take Heart America: A comprehensive, community-wide, systems-based approach to the treatment of cardiac arrest. *Crit Care Med*. 2011;39(1):26-33. DOI: 10.1097/CCM.0b013e3181fa7ce4

# ONLY A SITH DEALS IN ABSOLUTES

## Why we need both evidence-based & experience-based thinking in resuscitation research

By Paul E. Pepe, MD, MPH, FAEMS, MCCM, MACP

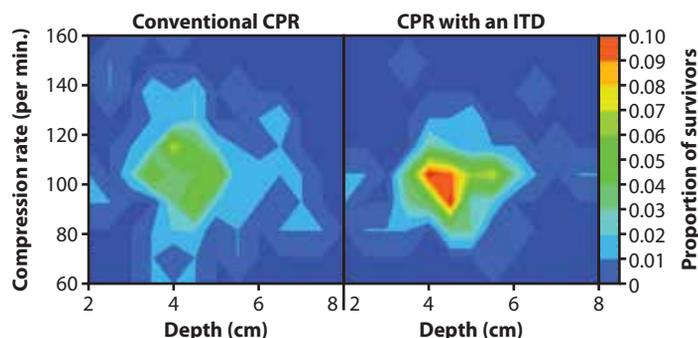
& Tom P. Aufderheide, MD, MS, FACEP, FACC, FAHA

For decades, reported survival rates and studies of interventions for out-of-hospital cardiac arrest (OHCA) have remained disappointing.<sup>1-3</sup> To improve outcomes, many respected organizations have developed widely adopted guidelines for both basic and advanced interventions, emphasizing an “evidence-based” process using published peer-reviewed literature.<sup>4,5</sup> Although these processes have had clear value, they also have their limitations.

Publications forming the evidence often have had conflicting information, statistical limitations, and even a lack of adherence to intended protocols, all leading to inconclusive findings.<sup>6</sup> Traditional controlled trials that test a singular intervention at a time may be one of the main reasons.<sup>7</sup>

Examining simple binary outcomes (i.e., effective or not) are affected by the time-dependent and multifactorial nature of OHCA cases.<sup>8-14</sup> For example, a single intervention (e.g., drug, AED) that’s highly effective when provided within minutes, may not be so helpful if too many minutes have elapsed.

Proper chest compressions—minimally interrupted with optimal



**Figure 1:** Optimal combinations of chest compression rate and depth indicated by green/yellow zones vs. blue/dark blue zones for neurologically intact survivors when comparing two types of CPR. CPR with an ITD had significantly higher likelihood of survival at and around 107 per min and 4.7 cm (red zones) vs. conventional CPR, but similar outcomes if the optimal chest compression rate/depth combination wasn't used.<sup>14</sup>

rate, depth and recoil—require proper coordination with the ventilatory variables that significantly impact circulation.<sup>9,10,12</sup> Effectiveness of interventions, including medications and CPR itself, can be compromised by these many interdependent factors that require the right timing and proper implementation.<sup>5,8,9,10,14</sup> (See Figure 1.)

All of these factors also need to be adjusted under certain conditions, particularly when flow-enhancing devices are used or when spontaneous circulation or respirations resume.<sup>9,12,14</sup> Accordingly, any proscribed “absolute” target or use for each of these circulatory, ventilatory, drug or procedural components, may need to be adjusted at any given time point and under different conditions.<sup>11-13</sup>

These complex dynamics have confounded many of our current evidence-based publications, even gold standard clinical trials.<sup>10,14</sup> Experience has now shown investigators that certain interventions deemed to be ineffective, or even harmful, in an evidence-based clinical trial (e.g., ITD, epinephrine, TXA) are actually very effective when quality CPR performance and/or physiologically sound ventilatory practices are used—or when the right patient population and timely intervention is used (e.g., TXA in severe traumatic brain injury).<sup>10,12,14,15</sup>

Important variables also include the populations served, residential infrastructures (e.g., many high-rises), traffic, geography, distances, climate, dispatch functions and the frequency and quality of early bystander CPR.<sup>2-8,12,16,17</sup> EMS system response configuration can significantly impact the skills of EMS personnel and therefore outcomes—as can the skills and resources of the receiving facilities.<sup>14,16-24</sup>

In essence, many interdependent components form a longitudinal (e.g., chain of survival) bundle of interdependent management for OHCA, where each must be simultaneously monitored, optimized, choreographed and properly implemented with time-appropriate and physiologically-driven approaches.<sup>10,12,14,15,18,25-27</sup> Attention to detail must extend from the dispatch center through eventual discharge from the hospital.

Most importantly, the concept that a single intervention, be it ET intubation, epinephrine, ITD, TXA or even defibrillation is absolutely good

or bad for the patient is a flawed conceptual approach.<sup>10</sup> All have value if used and implemented appropriately, and each could be harmful if not used correctly in the right setting.<sup>9–19</sup>

As Obi-Wan Kenobi once wisely admonished Anakin Skywalker in *Star Wars: Episode III – Revenge of the Sith*, “Only a Sith deals in absolutes” (i.e., things are simply either “good” or “bad”). Experience now tells us that there are no absolutes in resuscitation medicine; an intervention is neither simply “effective” nor “ineffective.” Accordingly, research should be re-spelt, “re-search,” particularly when cardiac arrest interventions that initially work so well in the laboratory setting end up falling short when first studied the clinical arena.

Hopefully, with these thoughts in mind, the deliberations in this groundbreaking congress about the *Future of Resuscitation*, involving many of the best minds in the field of resuscitation, will also help us better identify alternative approaches to saving lives using collaborative, open-minded thoughtfulness, conscientious innovation, and multidimensional grasp of the data.<sup>27</sup>



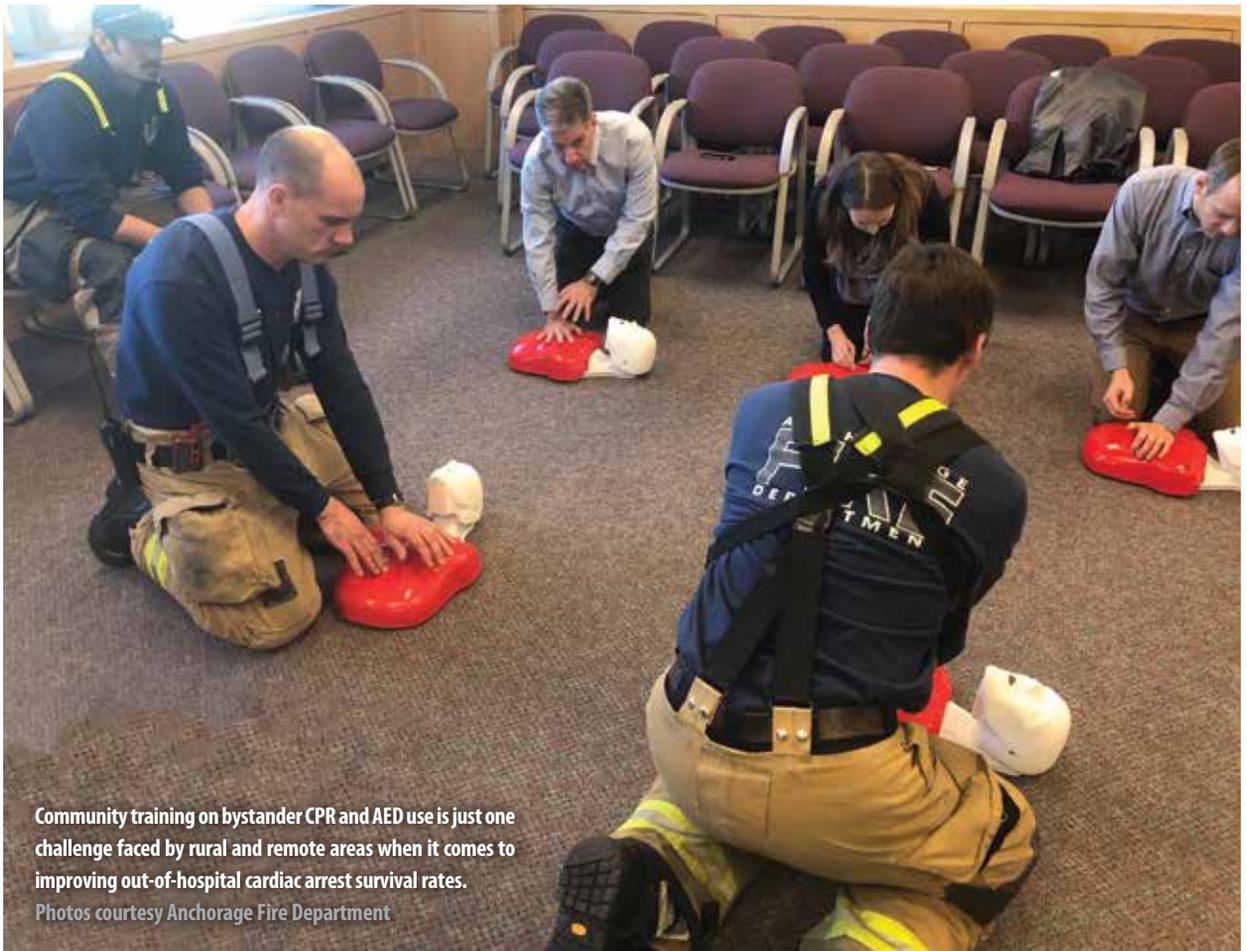
**Paul E. Pepe, MD, MPH, FAEMS, MCCM, MACP**, is coordinator of the Metropolitan EMS Medical Directors (“Eagles”) Global Alliance and EMS medical director for Dallas County, Texas. He’s also a professor in the Department of Management, Policy & Community Health, in the School of Public Health at the University of Texas Health Sciences Center in Houston.



**Tom P. Aufderheide, MD, MS, FACEP, FACC, FAHA**, is professor and associate chair for research affairs in the Department of Emergency Medicine at the Medical College of Wisconsin. He’s also medical director for the Clinical Trials Office at the Clinical and Translational Science Institute of Southeast Wisconsin and Director of the Resuscitation Research Center in the Department of Emergency Medicine at the Medical College of Wisconsin in Milwaukee.

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Community training on bystander CPR and AED use is just one challenge faced by rural and remote areas when it comes to improving out-of-hospital cardiac arrest survival rates. Photos courtesy Anchorage Fire Department

# THE RURAL RESUSCITATION BUNDLE

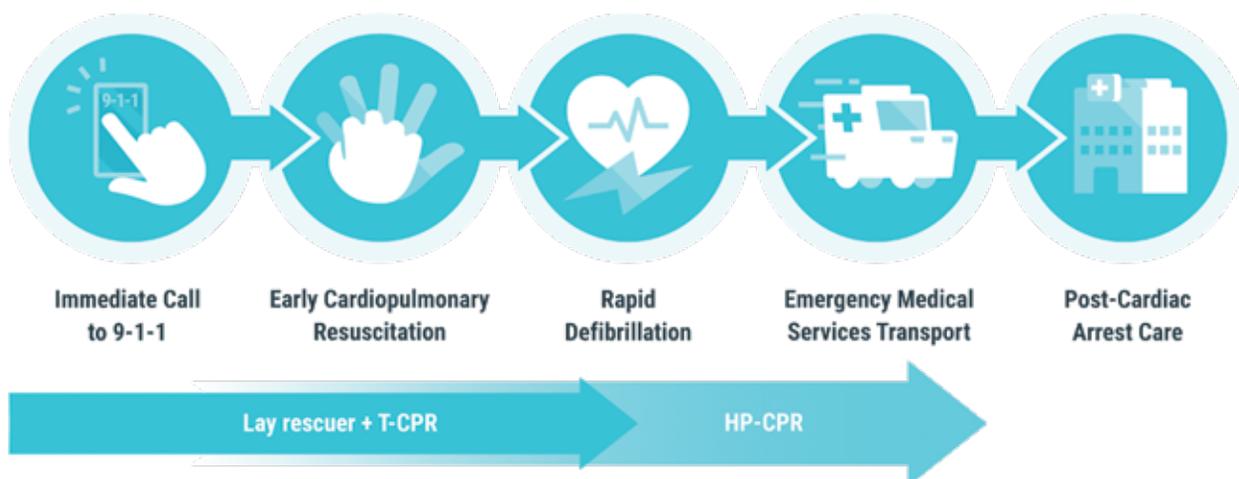
## AKA 'banning bucolic benign neglect of OHCA'

By Michael Levy, MD, FACEP, FAAEM, FACP

**A**t least 20% of the United States population lives in a rural setting. When looking at the cardiac arrest chain of survival and the “systems of care” in terms of rural lifestyles, geography and resources, it becomes immediately obvious that living inside a rural area means that your chance of survival from out-of-hospital cardiac arrest (OHCA) is significantly decreased compared to your urban counterparts. OHCA in a rural area has a 2-5 times worse outcome versus an arrest in a city or the suburbs.

All five components of the chain of survival/systems of care in an urban setting will usually lag behind those in an urban area. (See Figure 1.) Looking at each component individually and starting with access to 9-1-1, it's clear that all telephone CPR (T-CPR) isn't created equally: rural 9-1-1 often suffers from poor staffing and increased multitasking which might occur with co-dispatch of law enforcement, as well as fewer EMS response resources.

Early CPR requires either first responders or bystander CPR, and with rural EMS often staffed by volunteer providers, typically these agencies have longer response times—this leads to delays. Lower population density leads to decreased



**Figure 1:** Chain of survival for out-of-hospital cardiac arrest

likelihood of bystander CPR. The same theme of longer response times and fewer resources are also seen when looking at rapid defibrillation and EMS transport. Definitive care in small communities is likewise challenged by staffing and lack of high-tech resources.

A rural resuscitation bundle requires we commit resources and technology to leverage against the challenges of population density, distance and, to some extent, the lack of definitive local medical resources.

### WHAT CAN WE DO?

**T-CPR:** EMS call-taking is a highly leverage-able event that uses existing phone technology. Agreements could be put in place to have rural call centers pass off T-CPR to a larger T-CPR center of excellence, where operators could continue to coach and encourage the bystander in performing CPR while the slim resources at the rural dispatch center could focus on dispatch and continuing to process calls to 9-1-1.

**Wearable monitoring/alerting technology:** A huge challenge for rural life is that victims of OHCA may not be found before it's too late to resuscitate them. Technology currently exists in our wearable devices that can detect a sudden fall triggering a call to 9-1-1 which, if unanswered by the caller, can lead to immediate dispatch of resources to the GPS coordinates of the device.

**Community alerting/dispatch:** Knowing someone needs help is only

the first challenge; the second challenge is to quickly get someone to the victim, and for that we need to broadly implement “crowdsourced” OHCA alerting systems. There are a number of products available around the world including GoodSam and PulsePoint in the US, SAUV in Paris, the SCDF in Singapore, among many others.

In addition, by using an alerting system where the technology allows registered users to enter the residence of the victim holds the promise of improving the time to first CPR and buying time for more definitive care.

**Drone AED delivery:** Defibrillation is early definitive care that we know is one of the highest predictors of successful resuscitation. It is unlikely that we will ever have enough AEDs that they will routinely be found in rural and remote areas, however drone delivery of AEDs is an emerging technological solution.

You may already be familiar with plans for drones to deliver packages or meals to consumers, but there are also plans to deliver emergency care. Demonstration projects are now underway to design practical real-world applications for unmanned aerial vehicle technology—they are far beyond the “gee whiz” phase.

There are now a variety of drones available that can deliver payloads the size of an AED, however many projects remain on hold because of regulations that prohibit the uses of drones when the operator does not have visual line of sight control.

Work in this area will move us toward viable strategies for basing and launching AED drones at rural fire stations, hospitals or dispatch centers, possibly flown by skilled pilots at a central site that answer calls regionally or nationally.

**Linking rural hospitals with resuscitation centers:** Post-cardiac care performed in critical access hospitals or other small volume facilities will likely lag that provided in an urban resuscitation center. Support of the local hospital providers using telemedicine electronic ICU (e-ICU) models with predefined agreements may be of benefit, as well as protocols for transferring resuscitated patients via helicopter directly to tertiary care centers when those resources are available.

### CONCLUSION

Overall, the rural resuscitation bundle should start with community awareness of OHCA, extensive community training on bystander CPR and AED use and optimizing dispatch for best-practice T-CPR, but the bundle will also require the implementation of technological solutions that are now on the horizon if we want to move rural survival from OHCA to approach that of their big-city cousins.



**Michael Levy, MD, FACEP, FAAEM, FACP,** is the medical director for the Anchorage Fire Department and other agencies, as well as the EMS medical director for the state of Alaska. He's also the chief medical adviser for Stryker Emergency Care.



### **TRANSFORM YOUR TELEPHONE CPR & SAVE MORE LIVES**

Bystander CPR is one of the three highest value interventions for improving outcome from out-of-hospital cardiac arrest (OHCA). Early bystander CPR may also influence early defibrillation, which is the most important determinant of OHCA survival, since early CPR may prolong shockable rhythms.

Telephone CPR (T-CPR) seems to have similar outcomes to spontaneously provided bystander CPR and, therefore, T-CPR provides the ability to leverage the massive number of untrained citizens to effectively perform this lifesaving act. T-CPR can help provide early CPR to many if not most cardiac arrests, since about 70% of cardiac arrests happen in non-public locales.

Sadly, not all T-CPR is created equal; some T-CPR is superior to others.

#### **WHAT MUST BE DONE**

Telecommunicators must be trained to recognize cardiac arrest at the earliest possible moment during the 9-1-1 call, and then they must effectively direct the caller to perform CPR.

The best performing systems start every 9-1-1 call with the assumption that the call is a cardiac arrest until proven otherwise. These systems empower their dispatchers to move very quickly by asking the most important questions:

1. Is the person awake and alert? If the answer is “no,” then;
2. Is the person breathing normally? If the answer is “no” then;
3. Tell (not ask) the caller to perform CPR and begin the instructions that rapidly lead to the first compression.

This process mirrors the one from King County EMS in Washington: No-No-Go to CPR. An important corollary regarding the decision to start T-CPR is: “if there is doubt, there is *no* doubt.”

#### **GUIDE TO IMPLEMENTING T-CPR**

A good way to teach your EMS and dispatchers to implement high-performance T-CPR is to visit [www.ems.gov](http://www.ems.gov) and navigating to Projects > CPR LifeLinks. There you will find a rich set of free resources and a toolbox to guide your implementation of this critical component of public safety dispatch.

# A NATION OF RESPONDERS

## Optimizing BLS training is key to facilitating an effective citizen response to cardiac arrest in the Netherlands

By Hans van Schuppen, MD

**S**urvival after out-of-hospital cardiac arrest (OHCA) in the Netherlands is the highest of any country in Europe and among the highest in the world.<sup>1</sup>

The first links in the chain of survival have had a major influence on this achievement. Both telephone CPR instructions by the dispatcher, a nationwide civilian response system,<sup>2</sup> *HartslagNu*—translated from Dutch into English as *HeartbeatNow*—and dispatch of the immediate dispatch of police and fire to the patient has contributed to our high survival rate.<sup>3</sup>

### A CULTURE OF BLS

In the Netherlands, basic life support (BLS) is started before EMS arrival in 84% of OHCA's and an automatic external defibrillator (AED) is placed before EMS arrival in 65% of OHCA's.<sup>4</sup> BLS courses have been extensively implemented in the Netherlands and it's likely that this played a vital role in the overall 25% survival rate; nearly all patients who present in v fib or pulseless v tach are likely to survive.

There are five reasons the current BLS provider courses contribute to Holland's high survival rate:

1. Significant time spent on skills training;
2. Standardized PowerPoint presentation provided by the Dutch Resuscitation Council;
3. A focus on building both competence and confidence in the participants;
4. Specific attention is paid to recognizing cardiac arrest; and,
5. Lay persons are encouraged to register as a civilian responder after the course.

### BUILDING COMPETENCY

In past BLS courses, there was more attention paid to theoretical backgrounds with no practical consequences or relevance for the actual BLS skills. Today, there's an increased amount of time spent on hands-on training. The current BLS provider course almost exclusively focuses on the rationale of the OHCA algorithm and on how to perform the practical skills. In this way, more time and attention are spent on learning hands-on skills and optimizing performance.

The Dutch Resuscitation Council provides a standard PowerPoint presentation that's mandated for use during any and every BLS provider course.<sup>5</sup> This standardization is helpful in quality control, helps to prevent unnecessary or incorrect information and guarantees that all relevant topics are covered. BLS instructors are guided in how to best use this PowerPoint presentation in a BLS

instructor course. The layout, algorithms and figures contained in the PowerPoint are clear and easy to understand. In adherence to the guidelines of the European Resuscitation Council, we teach both ventilations and chest compressions in the 30:2 ratio.

Our BLS course weights high-quality CPR equally to the recognition of cardiac arrest. Too often laypersons interpret gasping as normal breathing, and they often misinterpret the spasm of the extremities that sometimes occurs at the beginning of cardiac arrest as a seizure.

To better teach these subtle yet important points, the Dutch Resuscitation Council produced a video with an actor mimicking a cardiac arrest and illustrating these aspects so the instructor can teach people that both gasping and extremity movement can occur and that this combination must prompt people to call for emergency dispatch and initiate BLS protocols.<sup>6</sup>

### BOOSTING CONFIDENCE

It is a primary objective for the BLS course to build both competence and confidence in the participants. This is done by emphasizing a positive learning environment and providing participants with constructive feedback. Confidence makes people more likely to be proactive in the case of an actual cardiac arrest. It also helps to reduce fear or uncertainty about what they should do. Confidence in the skills learned during training also helps to boost enrollment in the civilian response system which is encouraged during the course of the standard presentation.

At the end of the BLS course, participants understand the importance of starting BLS as soon as they recognize an OHCA—and they feel confident to do so. This knowledge and training, as well as confidence in the knowledge and training, is why many people register as a civilian responder after taking the provider BLS course. Today, the Netherlands now has a current total of more than 230,000 registered civilian

responders—equivalent to 1.4% of the national population.<sup>7</sup> A single national smartphone application directs these registered responders directly to the scene of the arrest.

### TARGETING IMPROVEMENT

The American Heart Association recently published a statement on educational strategies to improve outcomes from cardiac arrest.<sup>8</sup> In this thorough review, based on current evidence on medical education, various recommendations are made to make education and training more effective. The first author also published helpful infographics, which outline the eight different topic areas of the statement.<sup>9</sup> Both the statement and the infographics are highly recommended and were very helpful in improving the educational quality of our BLS provider course.

A working group of the Dutch Resuscitation Council is currently updating the BLS provider course program and instructional materials. There are several areas targeted for improvement.

Recertification currently takes place two years after the initial provider course, however, the evidence clearly indicates that the retention of skills is limited to only a few months. Therefore, refresher courses should be more frequent, and we are planning to invite providers for a short refresher course after one year instead of two. Furthermore, we strongly believe that mastery learning and deliberate practice (including rapid-cycle deliberate practice) can make the initial BLS training more efficient. By making the initial course shorter, we thus enable people to take the BLS course in a single evening.

Currently there's no specified program for the refresher course. The DRC working group envisions implementing a refresher course with an obligatory module of one hour, in which the basic OHCA algorithm and BLS skills are refreshed, as well as additional optional modules. These optional modules include additional skills such as the use of the pocket mask, but also scenario-based training focusing on civilian response situations including non-technical skills training. Furthermore, context-specific scenarios will be provided in a scenario book, which allows BLS instructors with valuable material to incorporate into refresher courses with specific groups (lifeguards, nurses, police officers, etc.).

### SHARING OUR BLS VISION

By illustrating the current and future of BLS education and training in the Netherlands, we hope to have inspired you to evaluate and improve the BLS provider courses in your system. To improve



**BLS courses have been extensively implemented in the Netherlands and it's likely this has played a vital role in the overall 25% cardiac arrest survival rate.**

**Photo courtesy Hartstichting/Dutch Heart Foundation**

outcomes in OHCA, we must make both laypersons and first responders confident to act, capable to recognize cardiac arrest, skilled to provide high-quality CPR and prepared to respond through step-wise, low-dose and high-frequent training that emphasizes real-life scenarios. Furthermore, we encourage the training of laypersons in BLS and the ability to register them as a civilian responder. If these citizen responders can be alerted to when their skills are needed, it can make a significant difference when a cardiac arrest occurs in their neighborhood.



**Hans van Schuppen, MD**, is an anesthesiologist at the Academic Medical Center in Amsterdam. His areas of interest include CPR, prehospital care, human factors and airway management. He also serves as a member of the education committee of the Dutch Resuscitation Society, a judge for the annual Dutch CPR Competition and on the organizing committee of the ResusNL conference.

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# AED ON THE FLY

## Drone delivery of AEDs for rural out-of-hospital cardiac arrest

By Sheldon Cheskes, MD, CCFP (EM), FCFP

**T**he future is now! The use of drones to improve outcomes from rural out-of-hospital cardiac arrest (OHCA) is an area that has garnered an incredible amount of interest in the prehospital community. Drones are the centerpiece of our community responder program in the Region of Peel in Ontario, Canada.

### TIME TO TREATMENT

Why would we use drones in rural OHCA? Because time-to-treatment plays a pivotal role in survival from cardiac arrest. Every minute of delay in defibrillation results in a 10% reduction in survival.<sup>1</sup>

The quickest way to save a life is for a bystander to provide immediate cardiopulmonary resuscitation (CPR) and to apply an automated external defibrillator (AED) to provide a shock to the heart. When an AED is not applied, survival from OHCA ranges between 5–15%, much lower than the 38% survival when an AED is applied and a shock is provided.<sup>2</sup>

When someone sustains a cardiac arrest in a rural or remote area, their hope of surviving diminishes rapidly because EMS providers often can't get to them fast enough.



**Real-world implementation of AED drone delivery to rural/remote locations is a worthwhile challenge that may facilitate other lifesaving applications.**

**Photos courtesy Sheldon Cheskes/AED on the Fly Drone Delivery Feasibility Study**

### URBAN VS. RURAL/REMOTE

The current systems for responding to cardiac arrest don't distinguish between urban and rural locations. At present, when an individual recognizes someone in cardiac arrest and calls 9-1-1, the dispatcher sends the closest fire or paramedic vehicle to the scene.

The problem with this approach for patients in cardiac arrest in rural and remote locations is two-fold. First, many rural and remote areas have no AEDs nearby for rapid defibrillation.

Second, in rural and remote settings, the best response times are rarely less than 10 minutes. Multiple studies comparing rural and urban survival rates from OHCA suggest EMS response time is a critical predictor of OCHA survival.<sup>3-5</sup>

Through use of mathematical modelling and system optimization, it was demonstrated that drone delivery could reduce the time to AED arrival in both rural and urban areas by 50%.<sup>6</sup> In the most urban region, the 90th percentile of AED arrival time was reduced by nearly 7 minutes, and in the most rural region, AED arrival time was reduced by 10.5 minutes.<sup>6</sup>

Research from Salt Lake County in Utah looked at the theoretical benefit of launching drones carrying AEDs from both urban and rural EMS stations.<sup>7</sup> Whereas only 4.3% of calls could have an AED delivered within one minute in the EMS response only model, greater than 80% of calls would have an AED delivered within one minute if a drone was launched from the EMS stations.<sup>7</sup>

A pilot study from Sweden reported the time to AED delivery using fully autonomous drones for simulated OHCA.<sup>8</sup> They found the median time from dispatch to arrival of the drone was 5 minutes compared to 22 minutes for EMS arrival.<sup>8</sup> The drone arrived more quickly than EMS in all cases, with a median reduction in response time of 16 minutes.<sup>8</sup>

### IMPLEMENTING DISRUPTIVE TECHNOLOGY

Although the concept of drone delivery of AEDs may sound alluring, the challenge is whether we can translate mathematical modeling of drone delivery into real-world implementation of disruptive technology.

This is the essence of the AED on the Fly Drone Delivery Feasibility Study. With grant funding from the Cardiac Arrhythmia Network of Canada (CANet) and ZOLL Medical Corporation we've completed our first set of feasibility flights of drone delivery of AEDs in the town of Caledon and Renfrew County, both in Ontario, Canada.

In our first simulation flights, we simultaneously

launched a drone from an EMS base with a responding EMS vehicle to a mock cardiac arrest. In all simulations the drone had shorter response times than EMS by anywhere from 2–4 minutes over a distance of 6.6 to 8.8 kilometers (4.1–5.5 miles), allowing for multiple shocks to be provided prior to EMS arrival.

Our second simulation scenario, over a larger geographic area, launched drones equipped with an AED from locations that were geospatially chosen as drone launch sites while EMS was dispatched from their usual base locations. With an EMS travel distance of 24 kilometers (nearly 15 miles) the drone handily improved response times from 8 to 9 minutes during the simulation scenarios, which aligns with our real-world plan for dispatch of drones equipped with AEDs.

All flights were conducted employing beyond visual line of sight (BVLOS) drones flying at speeds of up to 80 km/hr. To say, our first flights were a success would be an understatement.

### FUTURE IMPROVEMENTS

Although successful, further research is required before drone delivery of AEDs in rural areas becomes a reality. We have done qualitative research in our rural areas and the overwhelming feedback from residents is not regarding the use of drones to deliver an AED, but rather the use of the AED once the drone arrives.

Our current research will focus on improving the interface between the responder and the AED to simplify use as well as optimizing the drone descent and improving response times—all providing an opportunity to improve outcomes from OHCA.

Although the focus of our feasibility study is the timely delivery of AEDs for OHCA, there's great potential for drones to deliver other medications or technology for time sensitive emergencies, such as epinephrine for anaphylaxis, naloxone for opioid overdose, bleeding kits for hemorrhage control, and other everyday life-saving medications that may be difficult to acquire in or deliver to rural and remote locations. The potential benefits for other prehospital emergencies are limitless.

Drone-delivered AEDs are a potential transformative innovation in the provision of emergency care to patients suffering sudden OHCA. Further ongoing research will go a long way to making this once impossible dream into a reality.



**Sheldon Cheskes, MD, CCFP (EM), FCFP**, is the medical director for the regions of Halton and Peel in Ontario, Canada, and the Sunnybrook Center for Prehospital Medicine. He's an associate professor in the Department of Family and Community Medicine in the Division of Emergency Medicine at the University of Toronto. He's also a scientist at the Li Ka Shing Knowledge Institute at St. Michael's Hospital at the University of Toronto. He serves as a co-principal investigator for the Canadian Resuscitation Outcomes Consortium (CanROC) and is chair of the CanROC EMS Committee.

*In all simulations the drone had shorter response times than EMS by anywhere from 2–4 minutes over a distance of 6.6 to 8.8 kilometers (4.1–5.5 miles), allowing for multiple shocks to be provided prior to EMS arrival.*

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**An AED fits inside the cargo bay of a drone designed to be dispatched to a bystander who witnessed the cardiac arrest and called 9-1-1.**

# LESSONS FROM THE DEAD

## Use of human cadavers to learn how to improve clinical outcomes

By Joe Holley, MD, FACEP, FAEMS

**C**adavers have long been a key component of medical education. More recently, cadavers have been making an impact on our ability to better understand the physiology and science of CPR.

The development of an instrumented cadaver model with the ability to reveal pressures and flows has given us better insight into the physiology of CPR and provides some surprising findings.

Utilizing the instrumented cadaver model, we're now able to study the effects of various aspects of CPR, enhancements to standard CPR, and the effect these changes have on blood pressure and flow, and how we can improve perfusion in cardiac arrest.

Our areas of inquiry have included:

1. The study of intrathoracic pressure (ITP) and intracranial pressure (ICP) and cerebral perfusion pressure (CerPP) changes with active compression-decompression CPR with an impedance threshold device compared to standard CPR (S-CPR). (See Figure 1.)
2. ICP and CerPP changes with:
  - Head up and ACD+ITD CPR;
  - Incomplete chest wall recoil;
  - Impact of cervical collars;
  - Mechanical CPR with an ITD: flat vs. head up; and
  - The effect of airway devices on carotid flow during CPR.

Expanding on work in a porcine model, the cadaver model has demonstrated the differences between various methods of CPR,

**Figure 1: Comparing two methods of CPR**



Cadaveric comparison of standard CPR vs. ACD+ITD CPR, as well as mechanical CPR and head up devices, are now possible.

the utilization of enhancements and adjuncts in CPR, and even the effects of patient positioning during CPR on our ability to generate improved cerebral perfusion pressure.

Now that we can accurately visualize—in real time—the impacts of the quality of our CPR, we can better understand the important details that result in improved CPR.

For example, the model demonstrates the dramatic negative effect of poor-quality CPR compared to feedback-aided CPR. Dramatic changes can be made in blood pressure and cerebral perfusion pressure when we're performing CPR “at the sweet spot” related to rate, depth, location, and pauses.

Likewise, in the cadaver model, we can see the negative impact of elevated intrathoracic pressures during CPR. These elevated pressures are often the result of overventilation of the patient and inadequate chest recoil; both of which have proven to be significantly detrimental to perfusion.

Incomplete chest wall recoil during CPR (Figure 2) has been shown to:

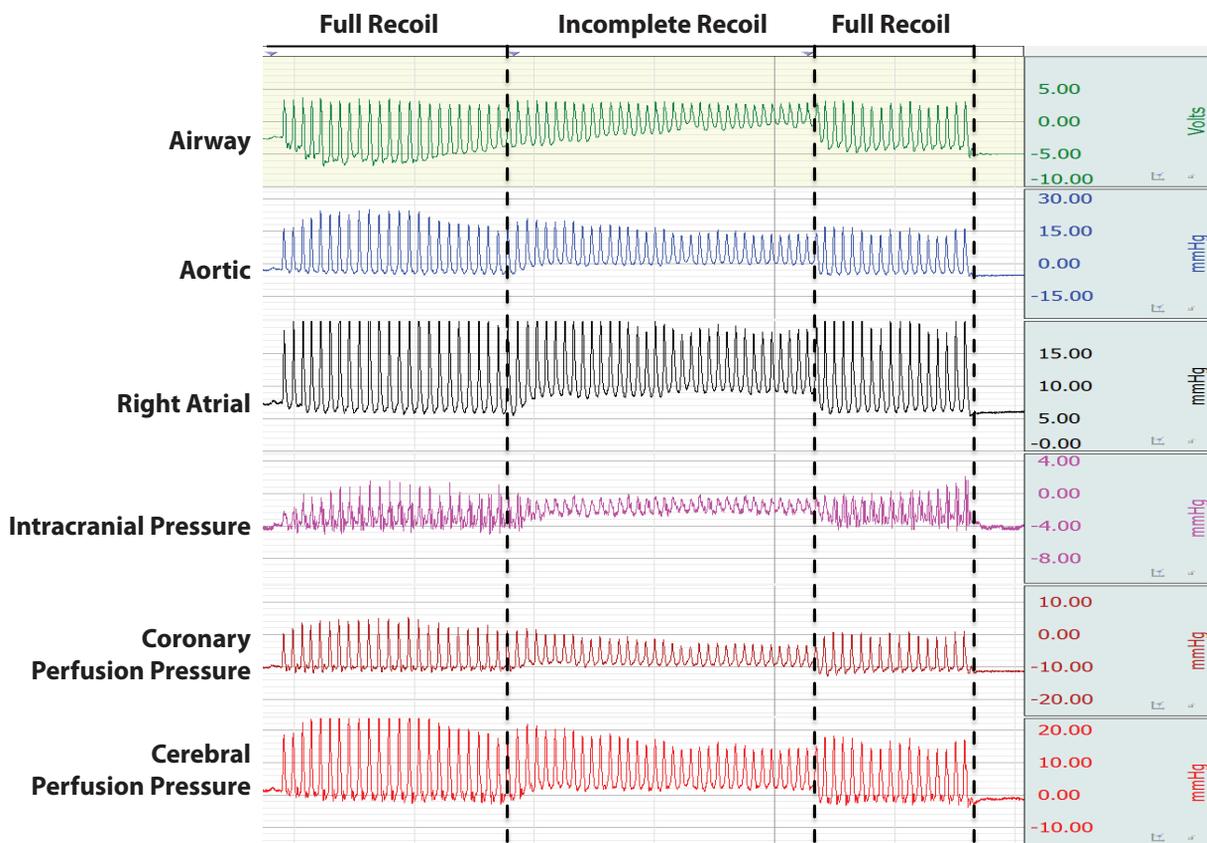
1. Cause persistent elevation of intrathoracic pressure despite ACD+ITD use;
2. Reduce venous return physiologically like a tension pneumothorax; and
3. Increase intracranial pressure and reduce cerebral perfusion.

The cadaver model also accurately demonstrates the impact of enhancement of the negative pressure or vacuum inside the chest during CPR. By harnessing the wider changes in intrathoracic pressure through the use of the devices such as the impedance threshold device (ITD), active compression/decompression (ACD CPR) devices and mechanical chest compression devices, we can see the improvement in cardiac output during CPR, as well as the reduction in intracranial pressure (i.e., resistance to flow). (See Figures 3–7.)

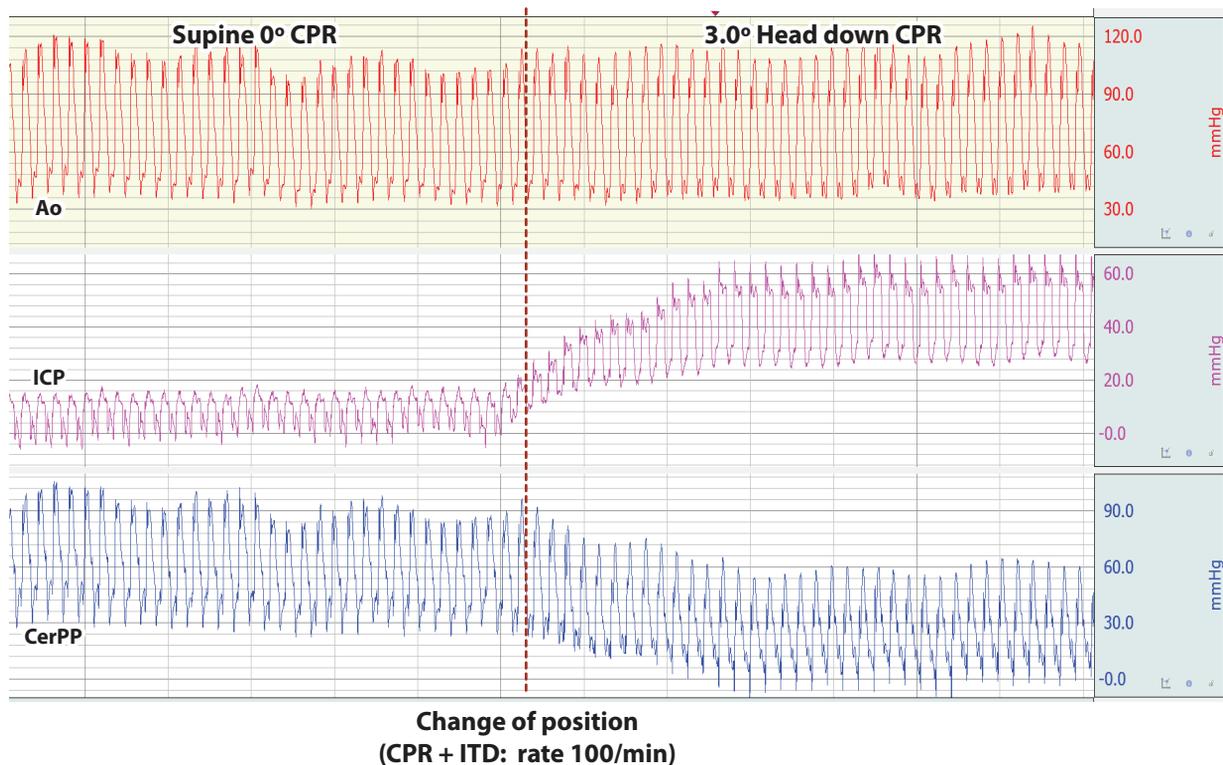
In addition, the benefits and pitfalls of head up CPR can also be demonstrated in the cadaver model. Improvements are shown in cerebral perfusion pressures with the elevation of the patient's head during high-quality CPR, but also brings to light procedural and performance issues that can result in a significant drop in brain perfusion.

We've studied what occurs as a result of elevating the head with circulatory enhancement

**Figure 2: Effects of incomplete chest recoil during CPR**

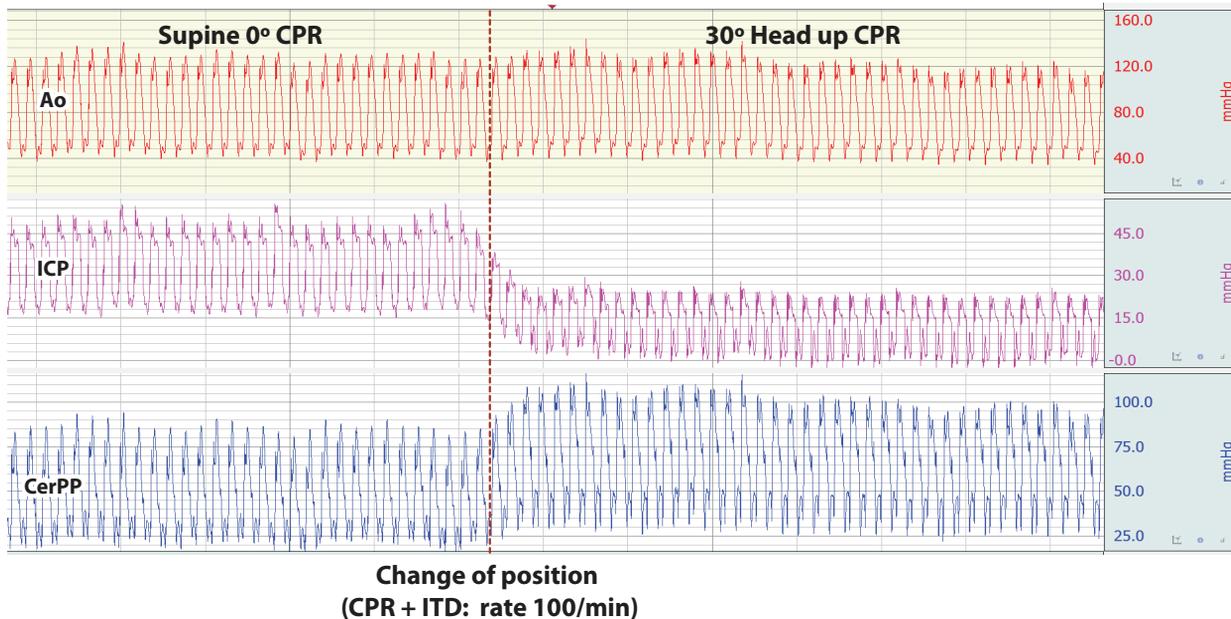


**Figure 3: Poor results when head is in the down position**



Results from: Debaty G, Shin SD, Metzger A, et al. Tilting for perfusion: Head-up position during cardiopulmonary resuscitation improves brain flow in a porcine model of cardiac arrest. *Resuscitation*. 2015;87:38–43. DOI:10.1016/j.resuscitation.2014.11.019

**Figure 4: Improved results when head is elevated during CPR phases**



Results from: Debaty G, Shin SD, Metzger A, et al. Tilting for perfusion: Head-up position during cardiopulmonary resuscitation improves brain flow in a porcine model of cardiac arrest. *Resuscitation*. 2015;87:38–43. DOI:10.1016/j.resuscitation.2014.11.019

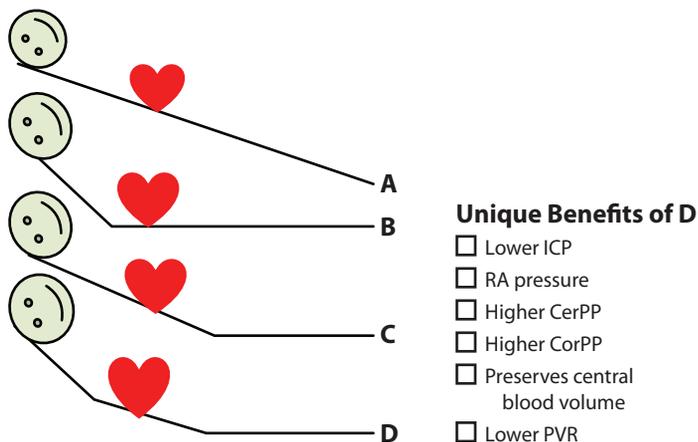
technologies (e.g., ITD and/or ACD and the EleGARD Patient Positioning System):

- Generate good flows;
- Increase brain blood flow;
- Reduce the concussion with each compression; and
- Lower intracranial pressure (ICP).

**UNEXPECTED FINDINGS**

As is often the case with research, the cadaver model has led to several unexpected findings. For example, the way we currently secure the airway device can negatively impact intracranial flow during low flow states such as CPR. Straps or devices that secure the airway can result in a tight ligature around the neck and inadvertently cause compression of the vasculature in the anterior neck resulting in poorer flow.

**Figure 5: Whole body tilt and just head/thorax tilt during CPR**



Similarly, the use of tightly placed cervical collars to prevent head movement after airway positioning can result in a similar compression of the vasculature in the anterior neck and result in poorer flow.

In a recent study utilizing this model, insights into the sealing ability of various supraglottic airways revealed that not all supraglottic airways are the same. We’re now required to reevaluate which supraglottic airway we utilize during cardiac arrest.

**CONCLUSION**

Through the amazing gift of body donation, we now have much better insight into many aspects of CPR, and these insights have already led to changes in our practice, and ultimately better outcomes for our cardiac arrest patients.

Cadaveric models have accurately reproduced physiologic findings from animal and human studies revealing important new physiologic impacts related to CPR and cardiac arrest management. Revelations regarding previously unrecognized details that can also affect outcomes show us that our knowledge is still lacking in many areas.



**Joe Holley, MD, FACEP, FAEMS**, is medical director of the Memphis (Tenn.) and Shelby County Fire Departments, and several municipal and private ambulance services in west Tennessee. He also serves as medical director for the Tennessee Department of EMS and is an associate professor in emergency medicine for the University of Tennessee Health Science Center.

**Figure 6: ACD+ITD CPR vs. ACD+ITD and head up (HUP) CPR**

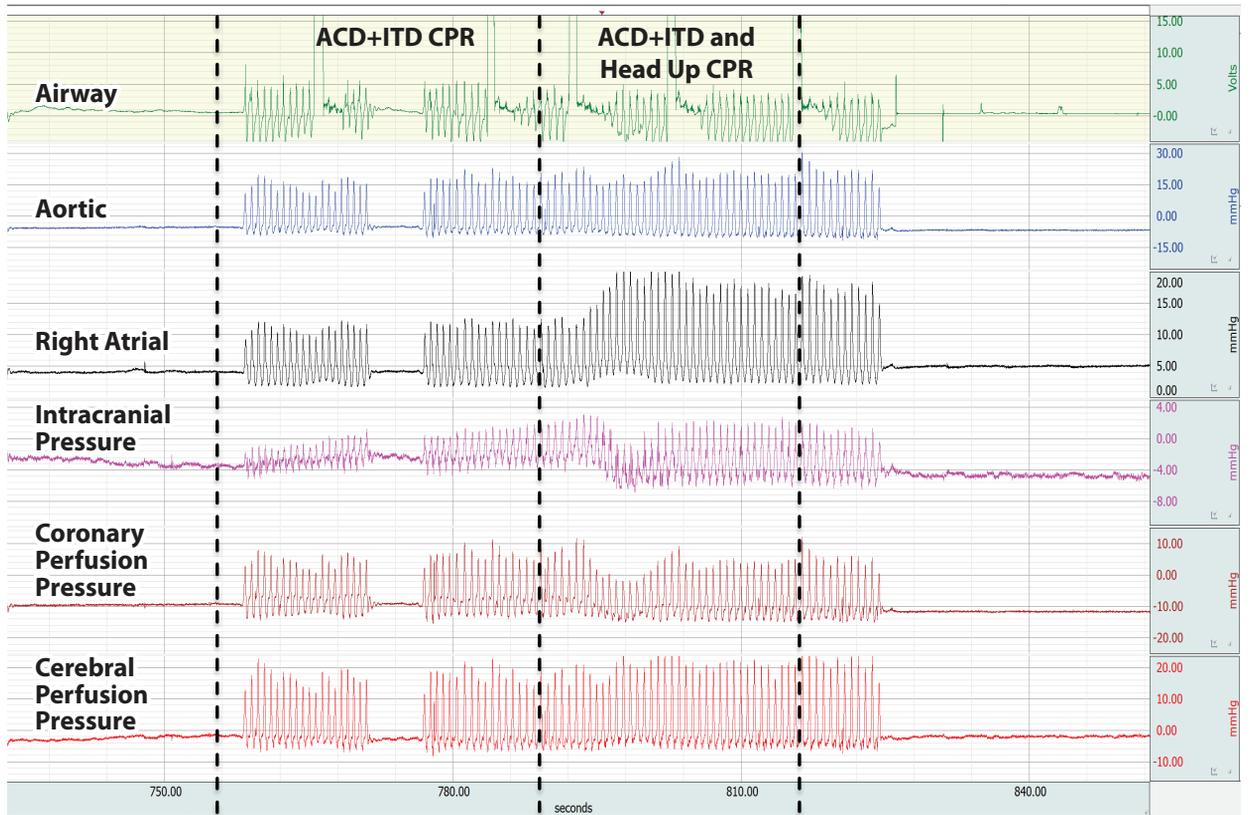
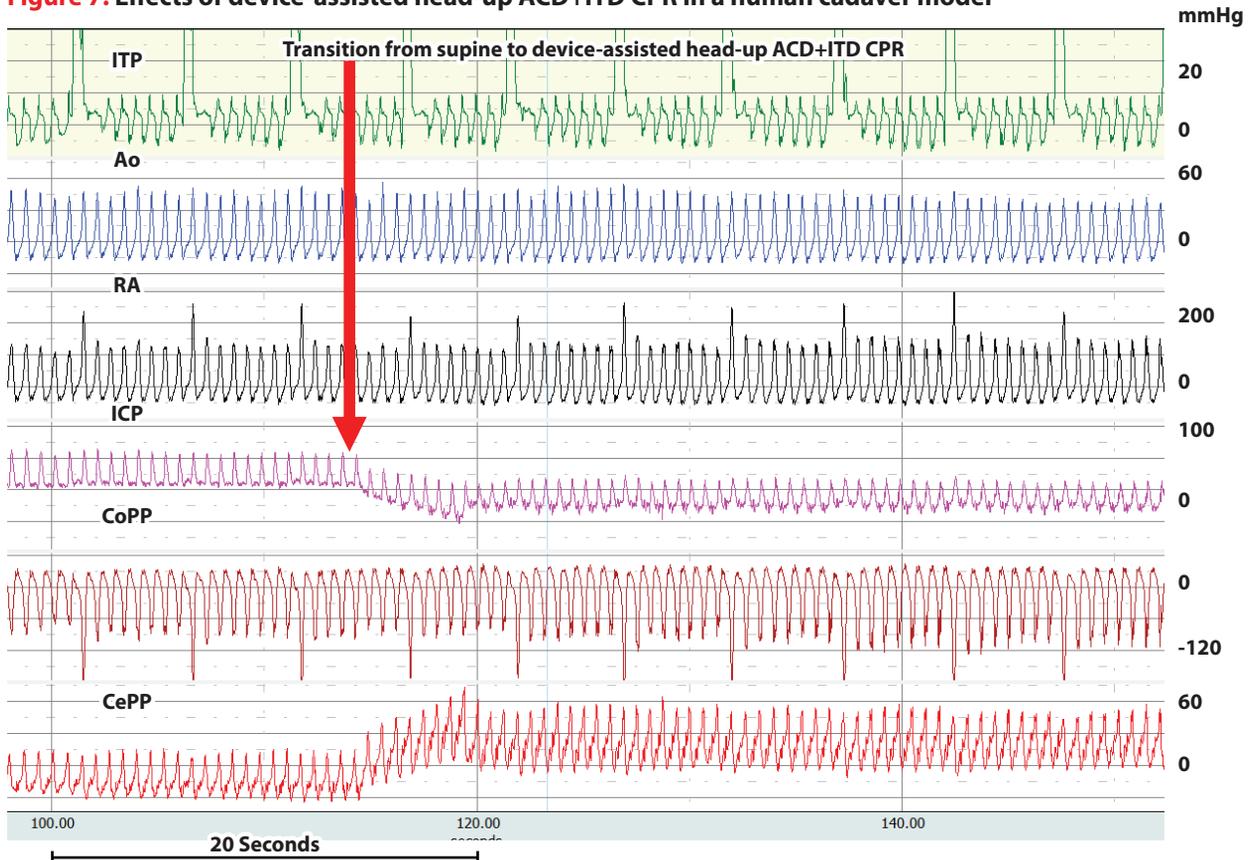


Figure courtesy MRS, LLC

**Figure 7: Effects of device-assisted head-up ACD+ITD CPR in a human cadaver model**





Prehospital use of ACD+ITD CPR devices can be readily adapted into existing BLS and ALS protocols to help EMS systems increase the likelihood of patient survival after cardiac arrest. Photo courtesy Regions Hospital/St. Paul Fire Department

# DON'T MIND THE PRESSURE, GO WITH THE FLOW

## Active compression-decompression CPR & impedance threshold devices

By Johanna C. Moore, MD, MSc

**I**t all started with an ingenious family member who successfully resuscitated his father by performing CPR with a common household plunger.<sup>1</sup> Speaking with the cardiologist taking care of his father in the hospital, the man said, “You should put a toilet plunger at the end of every bed.”

### IMPROVING PERFUSION

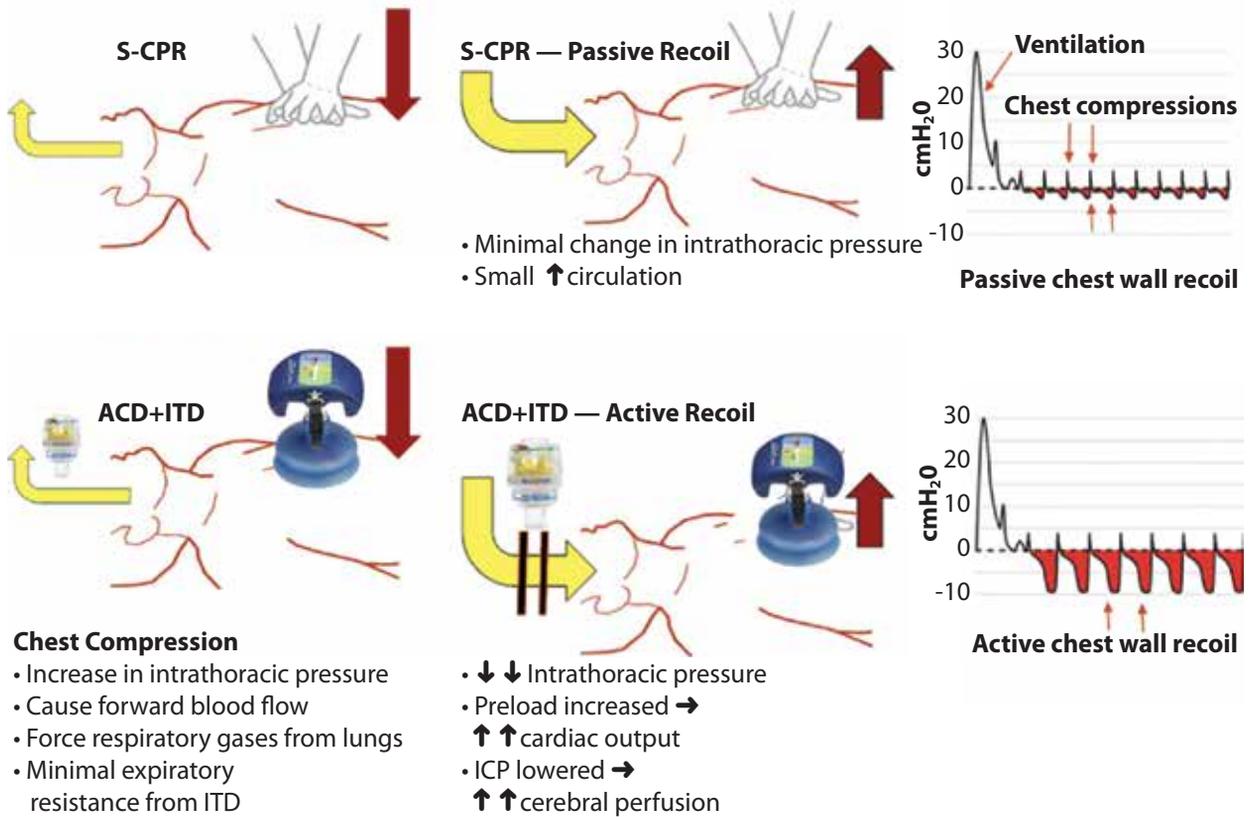
Over the past three decades, scientists have used this remarkable observation to discover the importance of generating negative intrathoracic pressure during the decompression phase of CPR.

A reduction in intrathoracic pressure occurs each

time we take a deep breath—or when a patient in cardiac arrest gasps. This lowers intracranial pressures and enhances venous blood flow back to the heart, thereby increasing cardiac output and ultimately improving cerebral perfusion. Today, this can be accomplished during resuscitation not by a plunger, but by using an active compression-decompression (ACD) CPR device together with an impedance threshold device (ITD).

The ACD CPR device by itself can generate some negative intrathoracic pressure during decompression, however, air rushes into the lungs at the same time and prevents the generation of

**Figure 1: ACD+ITD and standard CPR (S-CPR) techniques during CPR compression and decompression**

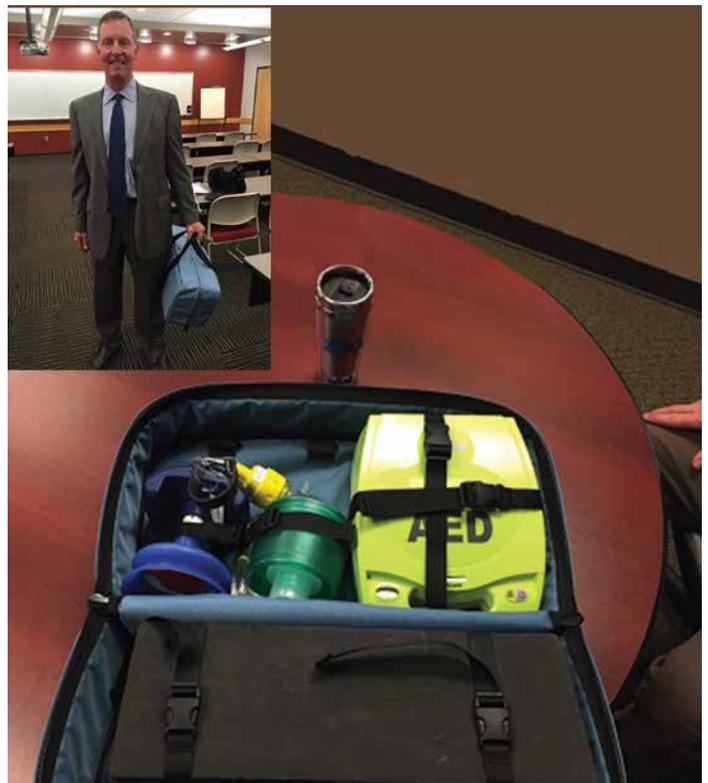


maximal negative intrathoracic pressure. The ITD was developed to enhance the amount of negative intrathoracic pressure achieved by blocking airflow into the lungs during the decompression phase of CPR. (See Figure 1.) It's ideally used with ACD CPR, but the ITD can also be used with standard CPR.

The ACD+ITD CPR combination has been assessed in both animal studies and human studies. In humans, it has been shown to lower intrathoracic pressures during CPR,<sup>2</sup> improve hemodynamics and circulation,<sup>3</sup> and improve both 1-hour and 24-hour survival after cardiac arrest.<sup>4,5</sup>

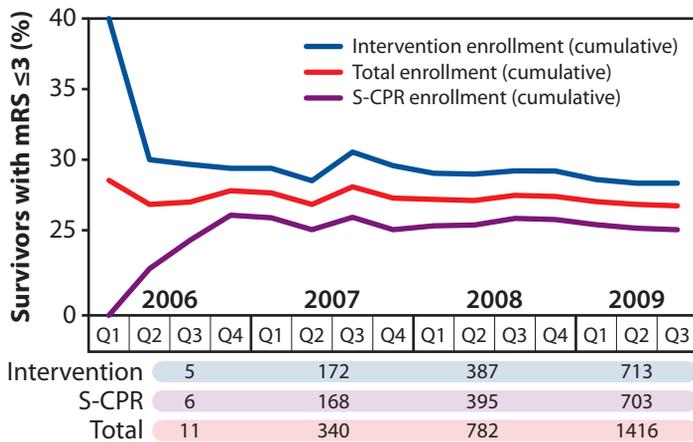
A prospective randomized prehospital trial of more than 2,700 patients showed an improved neurological survival benefit at hospital discharge, as well as at one year, in those treated with ACD+ITD as compared to standard CPR alone.<sup>6,7</sup> (See Figure 2.) This benefit was seen across all ages and presenting rhythms. (See Figure 3.) ACD+ITD CPR is the only system approved by the FDA in the United States to increase the likelihood of survival after cardiac arrest.

ACD+ITD CPR is commercially available in the U.S. and can be easily incorporated into practice by first responders. Like any other method or device used for the treatment of cardiac arrest, the ACD+ITD CPR devices should be used as part of

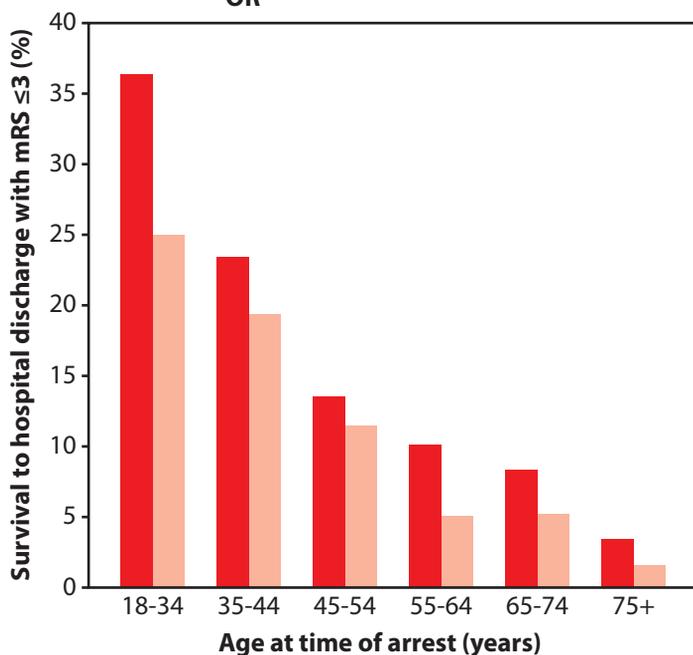
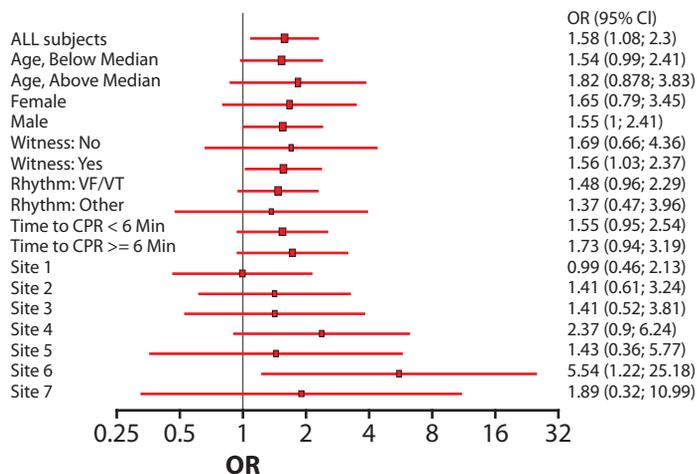


**Charles Lick, MD, is shown here with a hand-held first responder bag (left) that contains ACD+ITD devices, a bag-valve mask and an AED. Photo courtesy Johanna Moore**

**Figure 2: Neurological survival rate for ACD+ITD CPR (intervention) vs. standard CPR (S-CPR)<sup>6</sup>**



**Figure 3: ACD+ITD CPR (Intervention) benefits by subgroup and age<sup>6</sup>**



a larger bundle of care.<sup>8</sup> ACD+ITD CPR is best used by first responders immediately following a cardiac arrest. The prehospital use of ACD+ITD in BLS and ALS protocols can be flexible and adaptable to each EMS system. For example, in Minneapolis, ACD+ITD CPR is performed by first responders, and the patient will be transitioned to automated CPR with the ITD after 15 minutes and during transport.

## CONCLUSION

ACD+ITD CPR is one of only few interventions that have been shown to improve outcomes after cardiac arrest. As cardiac arrest survival rates remain low in the U.S., we should consider widespread and routine use of devices that regulate intrathoracic pressure.



**Johanna C. Moore, MD, MSc**, is an emergency medicine physician and laboratory research director for the Department of Emergency Medicine at Hennepin County Medical Center in Minneapolis. She also works with Hennepin County EMS in the management of cardiac arrest patients.

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# DEVICE-GUIDED HEAD-UP/TORSO-UP CPR

## Elevating the practice of resuscitation—one degree at a time

By Johanna C. Moore, MD, MSc

**W**hat's the best position of your patient's body during CPR? Convention dictates the supine position. However, when this wasn't an option and clinician-scientists were forced to think about whether it was best to transport someone head-up or feet-up in a small elevator, the concept of head-up position (HUP) CPR was born.

Over the past five years animal studies have demonstrated improved cerebral and coronary perfusion pressures,<sup>1-3</sup> improved blood flow,<sup>1,3</sup> and increased 24-hour neurologically intact rates of survival<sup>4</sup> with HUP CPR, when the head and torso are elevated during the performance of mechanical CPR with an impedance threshold device (ITD) or active compression-decompression CPR with an ITD (ACD+ITD CPR).

Similar to the reason we elevate the head of patients with traumatic brain injury, in swine and human cadavers HUP CPR is associated with an immediate decrease in intracranial pressure (ICP) vs. those in the flat position.<sup>1-4</sup>

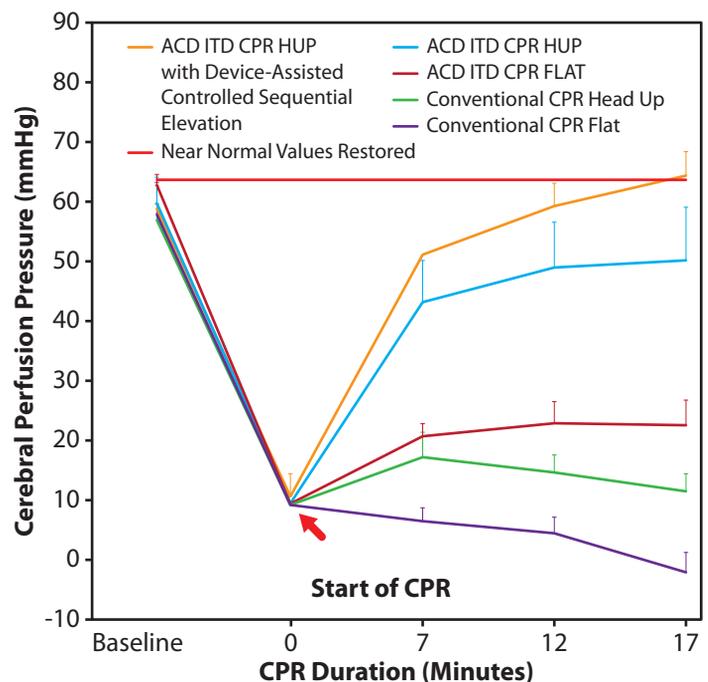
Venous blood drains from the brain due to gravity; mean aortic blood pressure is maintained with ACD+ITD CPR, and cerebral perfusion and coronary perfusion pressures increase.<sup>1,5</sup> It's also hypothesized that HUP reduces the likelihood of brain injury from mitigation of the high retrograde pressures generated with each compression in both the arterial and venous vasculature.<sup>1</sup>

There's much more to HUP CPR than simply elevating the head of the bed or elevating a stretcher during ongoing CPR. It's critical to generate flow to the cardio-cerebral circuit after the initial no-flow state, or downtime, by performing CPR in a supine position or minimally elevated position.

Our laboratory has consistently performed studies in this manner,<sup>2-6</sup> and disastrous outcomes have resulted when this principle has not been followed.<sup>7</sup> Elevation must be performed slowly, over a period of 2-4 minutes, as not to bottom out the aortic pressure.<sup>6</sup>

At present, the best combination we have found in animals is to use ACD+ITD CPR with slow sequential elevation over 2 minutes, resulting in cerebral perfusion pressures approaching baseline, or pre-cardiac arrest, values.<sup>6</sup>

The best hemodynamic and blood flow results have been observed with circulatory enhancement devices during CPR, optimally ACD+ITD CPR.<sup>2,6</sup> Conventional CPR alone has been tested with HUP CPR, and although mean cerebral perfusion pressures were significantly higher with HUP CPR, they were only 7% of baseline cerebral perfusion pressure values.<sup>2,8</sup> These values were incompatible with life. In contrast, near-normal cerebral perfusion pressure values can be achieved with ACD+ITD



**Figure 1:** Cerebral perfusion pressure over time during ACD+ITD HUP bundle of care in comparison with ACD+ITD and conventional CPR in the flat position

**Table 1: Guidelines on how to perform head up CPR**

Do's	Don'ts
1. Use circulatory adjuncts during CPR (e.g., ITD alone + standard CPR, automated CPR + ITD, ACD + ITD)	1. Perform head up CPR with standard CPR alone
2. "Prime" the cardio-cerebral circuit before elevation (120 seconds)	2. Raise the head of the patient immediately while in arrest
3. Elevate the head and chest/shoulders only during CPR	3. Don't elevate the whole body over prolonged CPR effort
	4. Elevate at a high angle, then come down, because there is a sequence effect

**Table 2: The bundle of care includes head up CPR**

Electrical	Circulatory	Metabolic	Refractory Arrest	Post ROSC
<b>0 to 4 minutes</b>	<b>4 to 10 (20?) minutes</b>	<b>10 (20?) to 60 minutes</b>	<b>&gt; 60 min, await ROSC post-cath</b>	
Immediate high-quality CPR	High-quality CPR	High-quality CPR	Continue eCPR	Therapeutic hypothermia
Defibrillation	Defibrillation	eCPR < 60 minutes	Cardiac catheterization	Maintain MAP (65? 80?) via pressors, fluids, active IPR therapy
<b>Head up CPR</b>	<b>Head up CPR</b>	Defibrillation	<b>Head up CPR</b>	<b>Head up position?</b>
Epinephrine	Epinephrine?	<b>Head up CPR</b>		Avoid hypoxia
	Anti-arrhythmics	Additional pharmacologic agents		

CPR and slow sequential elevation of the head and thorax.<sup>2,6</sup> (See Figure 1.)

We've created a list of "Dos and Don'ts" for HUP CPR,<sup>9</sup> as there's a misconception among some who have heard about this research that simply elevating the head and thorax during CPR is enough. (See Table 1.)

HUP CPR provides a unique opportunity to strengthen multiple steps in the overall bundle of optimal CPR and post-return of spontaneous circulation care. (See Table 2.)

### HEAD-UP CPR ON THE STREETS

Our experience to date in humans is limited but encouraging. Implementation of a bundled care methodology to improve resuscitation that included a head-up and torso-up chest compression system along with other changes significantly increased survival rates to hospital admission in Palm Beach County, Florida.<sup>10</sup>

Application of a new human patient positioning system that provides device-assisted controlled sequential elevation of the head and thorax during CPR is available for use in the United States.

In August 2019, a cardiac arrest was captured on surveillance video cameras at the Minneapolis-St. Paul International Airport where ACD+ITD HUP CPR, and automated CPR+ITD HUP CPR are both used during the care of this patient. After nearly 30 minutes of CPR, Greg, a 60-year-old traveler, was successfully resuscitated and is neurologically intact today. (See Video 1. Another remarkable success story is shown in Figure 2, p. 4.)

### CONCLUSION

HUP CPR shows great promise. Like any therapy, it must be performed correctly to be of benefit. If you are considering implementing HUP CPR, I encourage you to follow the outlined guidelines and to track your outcomes.<sup>6</sup>

It's imperative to realize that no one therapy is going to save every cardiac arrest, but rather a predetermined system of care will lead to success.



**Johanna C. Moore, MD, MSc**, is an emergency medicine physician and laboratory research director for the Department of Emergency Medicine at Hennepin County Medical Center in Minneapolis. She also works with Hennepin County EMS in the management of cardiac arrest patients.

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**Figure 2:** While at work in Little Rock, Ark., on Aug. 11, 2019, 44-year-old Darlene Skogen (shown here with EMS Quality Manager Edwin “Mack” Hutchison, MHA, EMT-P, at Metro EMS) had a spontaneous dissection of her left anterior descending (LAD) coronary artery and went into cardiac arrest. She was resuscitated on scene by medics from Metro EMS after 29 minutes of CPR with a LUCAS 3.1, an ITD-16, use of the EleGARD Patient Positioning System, epinephrine, and > 15 shocks from an AED. She was cooled to 33 degrees C. An angiogram showed a dissected LAD with flow. She was discharged on August 16, 2019, and is back at work, school, and caring for her three kids. The devices used on Darlene are shown on the manikin.

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**Video 1:** Watch the airport cardiac arrest save at <http://tiny.cc/MplsAirportSave>

# A COOLER WAY TO COOL

## Ultrafast cooling by total liquid ventilation

By Renaud Tissier, DVM, PhD

**T**argeted temperature management is recommended for post-cardiac arrest treatment in order to prevent neurological sequels and improve the patient's ultimate outcome. The ideal ways and targets for temperature management, however, are still debated and depend upon patient characteristics.

In laboratory studies, mild hypothermia (32–34 degrees C) universally provides great benefits compared to normothermia or sub-normothermia.<sup>1</sup> The apparent discrepancy between some of the clinical findings and the animal studies is in part related to different windows of application of the mild hypothermia episode in both settings.

For instance, hypothermia could be achieved within only a few minutes in rodents using external tools, due to their low body mass (e.g., 30 g in a mouse is 3,000 times smaller than a human) while most available techniques for a human require a couple of hours to provide systemic cooling of the entire body.

Therefore, animal studies investigate ultrafast cooling after cardiac arrest while clinical trials in humans investigate the effect of

hypothermia after a minimum of 3–6 hours after cardiac arrest. In order to increase the benefits provided by hypothermia, we still need new techniques providing very rapid cooling independently from body weight. This could provide similar benefits in small animals, large animals and humans.

### A NEW COOLING STRATEGY

For 15 years our group has worked on a new strategy that can use the lung as a heat exchanger, since the lung has a very large exchange area and a maximal flow rate, similar to the cardiac output at each cardiac beat.

To achieve this goal, we experimentally administer special fluids with excellent heat and gas exchange properties into the lungs of anesthetized animals. These liquids are perfluorocarbons. As compared to gas, these liquids have a high density that allows for thermal exchanges. These liquids also have very high solubility for oxygen and carbon oxide, in order to maintain normal gas exchanges while infused into the lungs. Their use during respiration is known as “liquid ventilation.”

This method has been previously proposed for

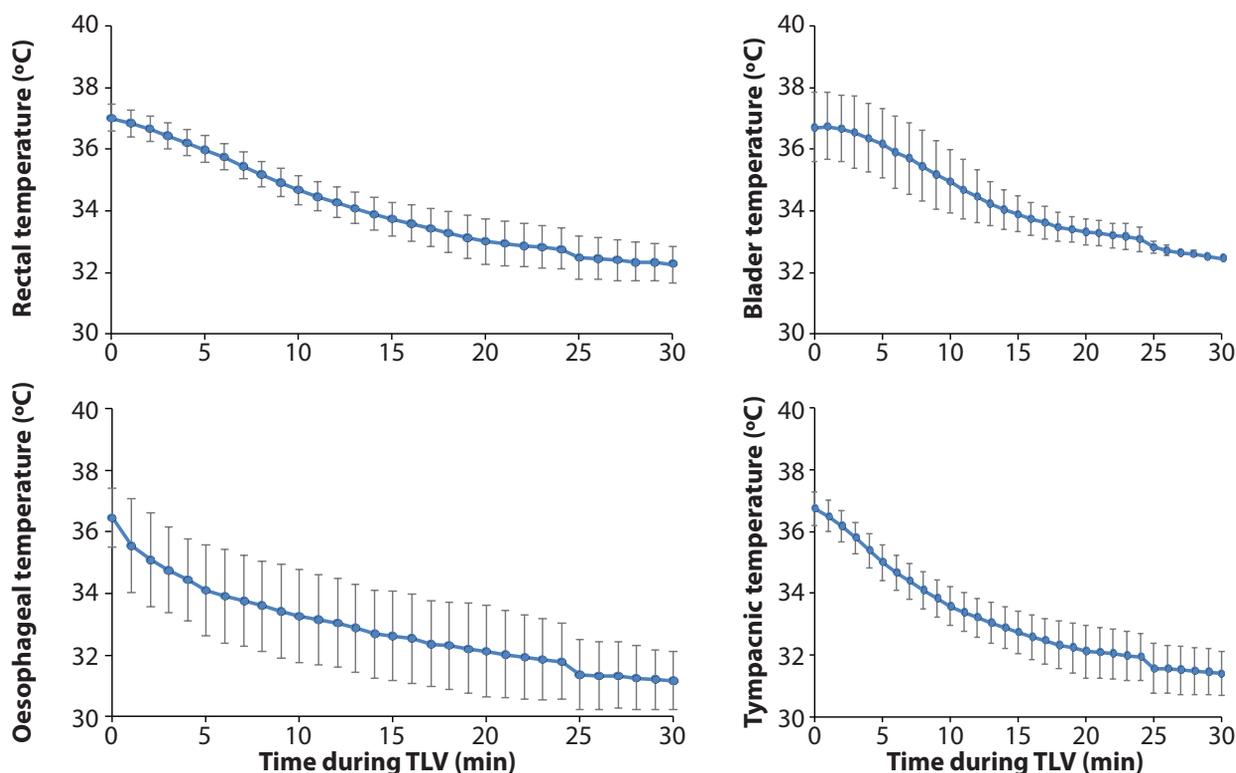
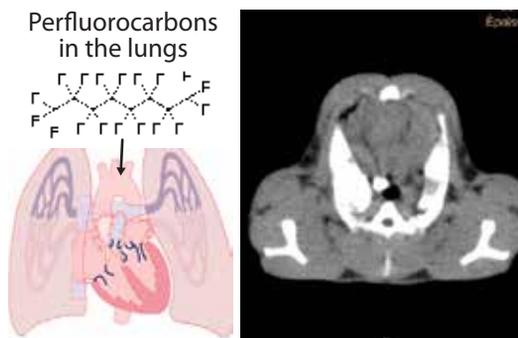


Figure 1: Summary of the cooling properties of liquid ventilation in large animals. Figures Renaud Tissier



**Figure 2:** Summary of the concept of liquid ventilation.

the treatment of multiple respiratory diseases, but the clinical findings were disappointing as the respiratory parameters were not appropriate and led to pulmonary complications.

In collaboration with engineers from Sherbrooke University, our group developed a new technique called “lung conservative liquid ventilation,” where we can accurately control the volumes and pressures of perfluorocarbons into the lungs. A dedicated device instills and removes a tidal volume of perfluorocarbons with each respiratory cycle, while allowing a minimal volume of this liquid in the lungs at the end of expiration.

Using this technique, we have demonstrated that total liquid ventilation can cool down the entire body of laboratory animals in less than 10 minutes (for richly perfused organs, such as heart and brain) to 30 minutes (for poorly perfused organs, such as fat and bones). This was shown in rabbits, lambs, sheep and pigs weighing up to 90 kg (198 lbs).

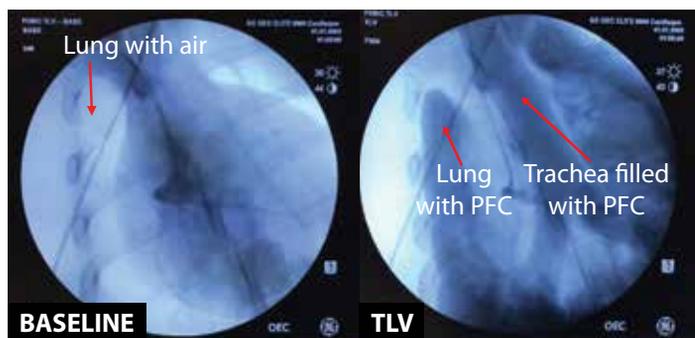
Ultrafast cooling through total liquid ventilation provided potent cardio-, neuro- and nephroprotective effects as compared to other cooling techniques in various experimental conditions such as models of myocardial infarction, shockable cardiac arrests, non-shockable cardiac arrest, organ donation, or abdominal vascular surgery.<sup>2</sup> We are continuing our working on this technique in order to be able to evaluate its clinical benefits in the very near future.

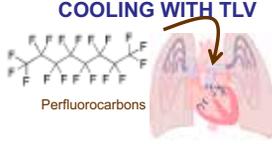


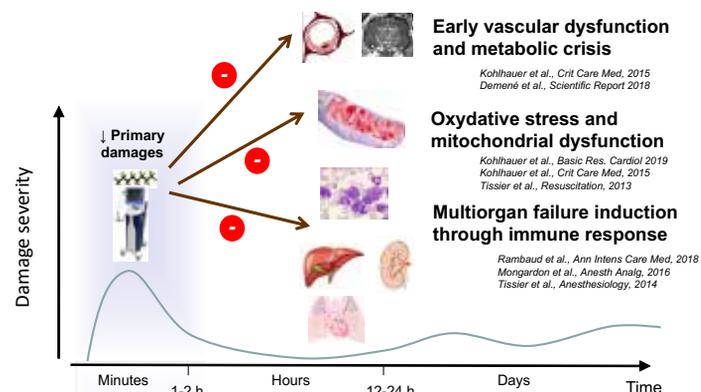
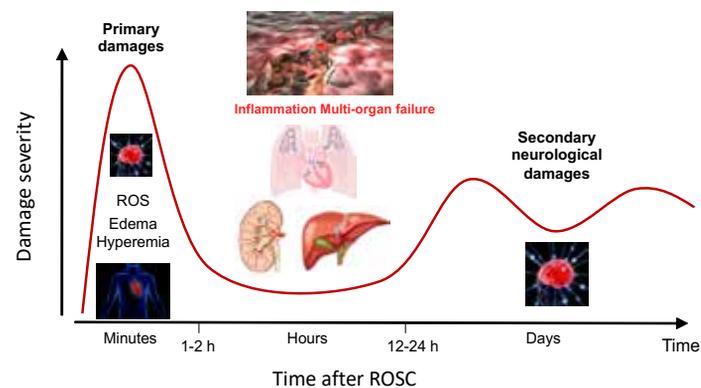
**Renaud Tissier, DVM, PhD**, is a professor at the Mondor Institute of Biomedical Research at the National Veterinary School of Alfort in Paris, France.

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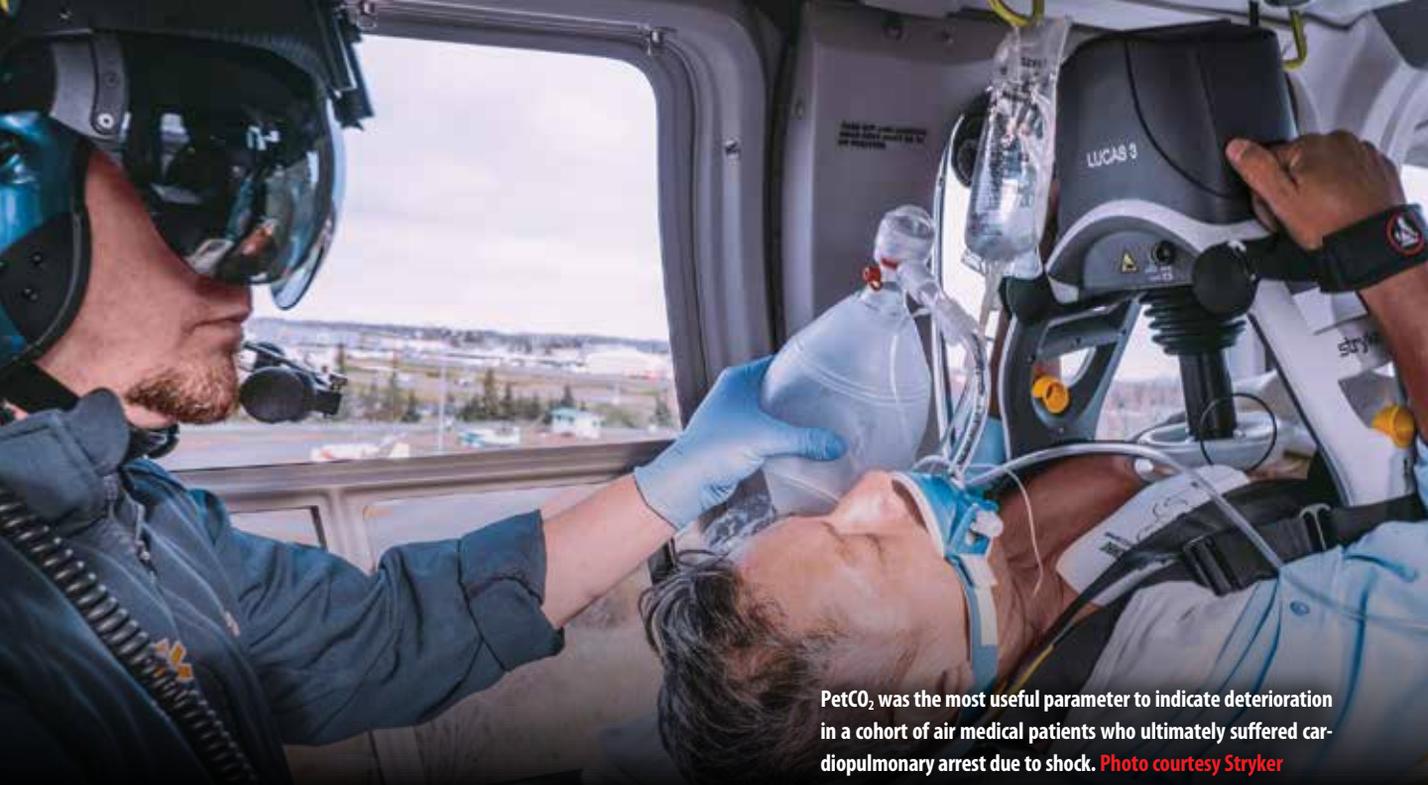
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 <p><b>Intra-arrest TLV...</b> Dr Kerber's work Riter et al., 2008 Staffey et al., 2009 Albaghadi et al., 2011</p> 	<p><b>Post-cardiac arrest</b> <b>Shockable cardiac arrest</b> Chenoune et al., <i>Circulation</i> 2011 <b>Shockable CA + STEMI</b> Darbera et al., <i>Crit Care Med</i> 2013 <b>Non shockable cardiac arrest</b> Kohlhauser et al., <i>Crit Care Med</i> 2015</p>	<p><b>Kidney protection (Organ donation)</b> Tissier et al. <i>Anesthesiol</i>. 2014</p> <p><b>Abdominal surgery</b> Mongardon et al. <i>Anesth Analg</i> 2016</p> <p><b>Spinal cord injury</b> Mongardon et al. <i>Ann Thorax Surg</i> 2018</p>
<p><b>COOLING WITH TLV</b></p>  <p>Perfluorocarbons</p>		
<p><b>Acute myocardial infarction</b> Tissier et al. <i>J Am Coll Cardiol</i> 2007 Tissier et al., <i>Cardiovasc Res</i> 2009 Chenoune et al., <i>Resusc</i> 2011 Darbera et al., <i>JCPT</i> 2012 Kohlhauser et al., <i>Bas Res Cardiol</i> 2019</p>	<p><b>Lung aspiration and lavage</b> Rambaud et al., <i>Ann Intens Care</i> 2018 Avoine et al., <i>Crit Care Med</i> 2011</p>	



**Figure 3:** Summary of the proof of concept studies (top panel) and putative action mechanism of liquid ventilation after cardiac arrest (bottom two panels).



PetCO<sub>2</sub> was the most useful parameter to indicate deterioration in a cohort of air medical patients who ultimately suffered cardiopulmonary arrest due to shock. Photo courtesy Stryker

# PROGNOSTIC METRICS DURING CPR

## Understanding PetCO<sub>2</sub>-to-PaCO<sub>2</sub> gradients

By Daniel P. Davis, MD

**C**arbon dioxide (CO<sub>2</sub>) is created as a byproduct of tissue metabolism. Tissue CO<sub>2</sub> passes quickly into capillary blood and is carried by the venous system to the lungs, where it's exhaled and can be measured with an inline or side-stream capnometer.

The ability of capnometry, or its graphical form capnography, to reliably identify correct placement of an advanced airway is well documented and has become the standard of care. However, the observation that the end-tidal CO<sub>2</sub> (PetCO<sub>2</sub>) value does not always equal the CO<sub>2</sub> concentration from an arterial blood sample (PaCO<sub>2</sub>) has resulted in some confusion and mistrust surrounding its accuracy.

The difference between PetCO<sub>2</sub> and PaCO<sub>2</sub> reflects the dilution of CO<sub>2</sub> in exhaled gas by dead space in the lungs. Most clinicians are familiar with the concept of “anatomic dead space,” which

represents the upper portion of the respiratory tree that doesn't participate in gas exchange (e.g., trachea, mainstem bronchi, and upper divisions of the bronchial tree).

The ability of anatomic dead space to dilute the measured CO<sub>2</sub> concentration of exhaled gas can be minimized by recording the value at the end of each breath (i.e., end-tidal), when the anatomic dead space has already been exhaled.

The interference of anatomic dead space with PetCO<sub>2</sub> is minimal unless exhaled breaths are so shallow as to fail to completely empty the anatomic dead space with each breath, or in severe reactive airways disease, in which exhalation is so constricted that dead space mixing occurs.

More challenging is the presence of “physiological dead space,” which occurs in states of low perfusion when portions of the lung no longer receive blood and thus receive no CO<sub>2</sub>. Even recording CO<sub>2</sub> concentration at the end of each breath cannot account for the “dilution” of exhaled CO<sub>2</sub> by non-perfused lung segments.

In fact, the lower the cardiac output, the greater the ratio of non-perfused to perfused lung segments and the lower the PetCO<sub>2</sub>-to-PaCO<sub>2</sub> gradient.

## END-TIDAL CO<sub>2</sub> & SHOCK

The relationship between cardiac output and PetCO<sub>2</sub> can be exploited to provide an accurate measure of perfusion status in critical patients. Previous investigators have documented high correlation between cardiac output and PetCO<sub>2</sub> using both experimental and clinical data.

Our own research has revealed the following observations:

- The PetCO<sub>2</sub>-to-PaCO<sub>2</sub> gradient was an earlier indicator of changes in perfusion status (either improving or worsening) with less random variability as compared to mean arterial pressure (MAP), base deficit, or lactate in a population of critically ill or injured surgical ICU patients.
- High correlation between PetCO<sub>2</sub> and MAP was observed in intubated air medical patients. Furthermore, improvements in PetCO<sub>2</sub> were often observed before a MAP increase in response to therapeutic interventions.
- PetCO<sub>2</sub> was the most useful parameter to indicate deterioration in a cohort of air medical patients who ultimately suffered cardiopulmonary arrest due to shock. Initial PetCO<sub>2</sub> values were nearly normal, with a gradual decrease over 3–45 minutes until a threshold PetCO<sub>2</sub> value of 25 mmHg was reached, at which point patients deteriorated rapidly into cardiopulmonary arrest.
- A decrease in PetCO<sub>2</sub> < 25 mmHg is now included as one of the criteria for aggressive rescue therapy to prevent cardiac arrest (blood transfusion, push-dose pressors, resuscitative ventilation mode, pacing/cardioversion for dysrhythmias, cardiopulmonary bypass).

## END-TIDAL CO<sub>2</sub> & CARDIAC ARREST

The relationship between cardiac output and PetCO<sub>2</sub> isn't limited to perfusing patients. Not only can capnography be used to confirm advanced airway placement in patients undergoing CPR, but we have made several other observations about PetCO<sub>2</sub> in arrest victims:

- Accurate PetCO<sub>2</sub> values can be recorded with bag-valve mask (BVM) ventilation as well as via an advanced airway. PetCO<sub>2</sub> values recorded with BVM are 3–4 mmHg lower than through an endotracheal tube or supraglottic device (e.g., King or laryngeal mask airways).
- The accuracy of PetCO<sub>2</sub> values depends on consistent tidal volumes > 250 mL to avoid “dilution” with anatomic dead space. This can be ensured by using “upstroke ventilation,” in which a breath is delivered during the recoil phase of every 10th chest compression. This

*A decrease in PetCO<sub>2</sub> < 25 mmHg is now included as one of the criteria for aggressive rescue therapy to prevent cardiac arrest.*

strategy appears to have other benefits, including avoidance of hyperventilation, decreased driving pressures, and increased cardiac output.

- PetCO<sub>2</sub> values recorded during CPR are predictably lower than PaCO<sub>2</sub> values due to the decreased cardiac output. Initial PetCO<sub>2</sub> values > 30 mmHg indicate hypercapnia as would accompany pre-arrest respiratory insufficiency, potentially underscoring the importance of ventilation during CPR.
- Better CPR is indicated by a rising PetCO<sub>2</sub> over baseline. We have documented the successful use of PetCO<sub>2</sub> to optimize chest compression rate, depth, and recoil for each individual patient. Future applications may include adjustment of compression-to-ventilation ratios. Changes in CPR require 15–20 seconds for PetCO<sub>2</sub> “equilibration.”
- Shock success increased sevenfold among inpatients with primary v fib arrest once PetCO<sub>2</sub> values rose above 25 mmHg. This suggests arrest protocols in which defibrillation attempts are delayed for three or more minutes of CPR until adequate “priming” can be achieved.
- The inability of high-quality manual CPR to increase PetCO<sub>2</sub> values may suggest need for adjuncts, such as intrathoracic pressure therapies (e.g., ResQPOD, ResQPUMP, mechanical CPR devices, torso elevation, or cardiopulmonary bypass). Conversely, a decrease in PetCO<sub>2</sub> with implementation of one of these adjuncts (e.g., manual-to-mechanical CPR) may suggest a return to the previous CPR strategy.
- Salvageability is indicated by rising PetCO<sub>2</sub> values or steady PetCO<sub>2</sub> values > 25 mmHg. Futility is indicated by decreasing PetCO<sub>2</sub> values despite optimal CPR. Although current guidelines suggest futility with PetCO<sub>2</sub> values < 10–15 mmHg, such low values are rarely observed in hospital arrest or in out-of-hospital cardiac arrest with high quality CPR.



**Daniel P. Davis, MD**, provides research and training direction for Air Methods Corporation. I also provide medical direction for Mercy Air Medical Service and Riverside County Fire Department and work in the ED at Bear Valley Hospital and Catalina Island Medical Center.



End-tidal carbon dioxide is an excellent guide to use for monitoring the progress of cardiac arrest resuscitation. Photo courtesy Prince George's County EMS

# COMPELLING TELLINGS FROM EXPELLINGS

## Monitoring end-tidal carbon dioxide during cardiac arrest

By Marvin A. Wayne, MD, FACEP, FAAEM, FAHA

**W**e all have it, some of us use it, but few use it to its full potential. I'm referring to the measurement of end-tidal carbon dioxide (EtCO<sub>2</sub>). Capnography gives us the ability to optimize survival after cardiac arrest.

The concentration of carbon dioxide in the air we breath is 0.03%. Adults, at rest, produce approximately 2.5 mg/kg/min. This waste product of metabolism is then transported in one of three forms, in the blood, to the lungs where it is cleared by alveolar ventilation:

- 60% to 70% is converted by carbonic anhydrase and then bound to the bicarbonate ion;
- 20% to 30% is bound to proteins—the most available is hemoglobin; and
- 5% to 10% is dissolved in physical solution, we know this as the PCO<sub>2</sub>, and it is and exhaled via ventilation.

The driving pressure for CO<sub>2</sub> elimination is the partial pressure difference between the CO<sub>2</sub> in the pulmonary capillary and the alveolar air. Equilibrium is reached in < 0.5 seconds.

Exhaled CO<sub>2</sub> is typically measured at the point of maximal exhalation, which is termed end-tidal carbon dioxide (EtCO<sub>2</sub>). In some cases, measurement of total CO<sub>2</sub> clearance is also of clinical value. ETCO<sub>2</sub> can be displayed graphically (i.e., capnometry) and numerically (i.e., capnography).

ETCO<sub>2</sub> is usually measured either mainstream, where the sensor and optical sensor is in line with the inhalation/exhalation port of airway adjunct, or sidestream, where there is an aspiration device that transfers to the optical sensor.

EtCO<sub>2</sub> is reported in different ways in various parts of the world. In North America, most reporting is in partial pressure or mm/Hg. It can also be reported in percentage, with 1% equaling 7.6 mm/Hg. In Europe and other countries, it's often reported in Kilopascal, kPa, with 1 kPa equaling 7.6 mm/Hg.

Factors affecting PaCO<sub>2</sub> include delivery (i.e., blood flow) and elimination. Delivery reflects cardiac output and is significantly affected by cardiac arrest, CPR and shock. Elimination, on the other hand, is primarily a factor of ventilation, with results being directly and indirectly related to minute ventilation and tube placement.

### CAPNOGRAPHY AS A GUIDE

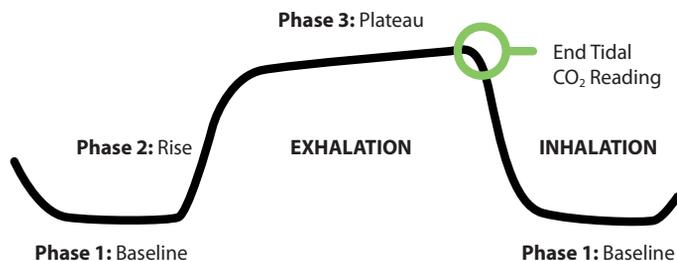
Prehospital, as well as in-hospital EtCO<sub>2</sub> values may be affected by a variety of diseases. These include asthma, COPD, hyperventilation with incomplete emptying, as well as inadequate tidal volumes.

Clinical applications for prehospital care are primarily focused on tube placement, or dislodgement, progress or failure of resuscitation, and, in the non-arrested patient, indications of obstructed airway disease. It may also be useful to follow the progress of shock resuscitation in the non-arrested patient.

One very important parameter is its use to follow the progress or failure of cardiac arrest resuscitation. Studies performed in the 1990s outline that potential and real use.<sup>1,2</sup> This includes a real-world study carried out for a total of 650 patients with consistent findings.

Although study limitations are noted, the conclusions have impact for resuscitators and resuscitations. Limitations included patient numbers and the effects of epinephrine, sodium bicarbonate, and minute ventilation. Best effort was used to compensate and corollate for these effects. Our conclusions were that EtCO<sub>2</sub> may be a marker of non-resuscitability, and that it should not be used

**Figure 1: Normal end-tidal carbon dioxide capnography waveform**



**Figure 2: Capnography waveform indicating ROSC after cardiac arrest**



alone but with other parameters, such as asystole, to cease resuscitation.

It should be noted that EtCO<sub>2</sub> is also an excellent guide for monitoring the progress of resuscitation, including assessing the efficacy of CPR and also of rescuer fatigue.

It may also be able to show the efficacy or failure of CPR adjunct devices, such as the ResQCPR cardio pump, the ResQPOD ITD, mechanical chest compression devices, and head-up CPR. In the future, new technology and techniques may be evaluated by their effect on EtCO<sub>2</sub>.

### CONCLUSION

In conclusion, EtCO<sub>2</sub> may be a marker of resuscitation progress, with efforts to improve falling values, such as changing rescuers for rescuer fatigue or shifting to mechanical devices. In combination with other parameters, it may be used to cease resuscitative care. It's clearly technically feasible and should be a significant part of both prehospital and in-hospital care.



**Marvin A. Wayne, MD, FACEP, FAAEM, FAHA**, is medical program director of Whatcom County, Washington and associate clinical professor at the Department of Emergency Medicine at the University of Washington.

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# TACKLING THE BIG ONE

## Los Angeles County regional system of cardiac arrest care

By Nichole Bosson, MD, MPH, FAEMS

**L**os Angeles (LA) County is a sprawling metropolis with a total population of 10.2 million people. EMS responds to nearly 8,000 out-of-hospital cardiac arrests annually by 30 municipal fire departments and 1 law enforcement agency with over 4,000 licensed paramedics.

Field protocols emphasize on scene resuscitation with manual high-quality CPR and minimized interruptions. For patients meeting criteria based on medical futility, termination of resuscitation in the field is supported by an official policy.

After return of spontaneous circulation (ROSC), or for patients who have other reasons for transport such as refractory v fib, paramedics transport directly to one of 36 designated cardiac arrest receiving centers. These centers can provide immediate coronary angiography and primary percutaneous coronary intervention (PCI) 24 hours per day, 7 days per week, have an institutionally approved targeted temperature management (TTM) protocol that adheres to LA County guidelines, and have cardiovascular surgeons available.

All designated cardiac arrest centers are required to submit quality improvement (QI) data, including demographics, in-hospital management, and outcomes, on all patients treated after OHCA to a single registry maintained by the LA County EMS Agency.

Data are used by the LA County EMS Agency Data Management Section to generate reports for hospital and systemwide QI, which are disseminated at semi-annual system meetings.

Since LA County regionalized cardiac arrest care, the overall survival rate for OHCA patients with initial shockable rhythm

is 37%, of whom 57% survive with good neurologic outcome.<sup>1</sup>

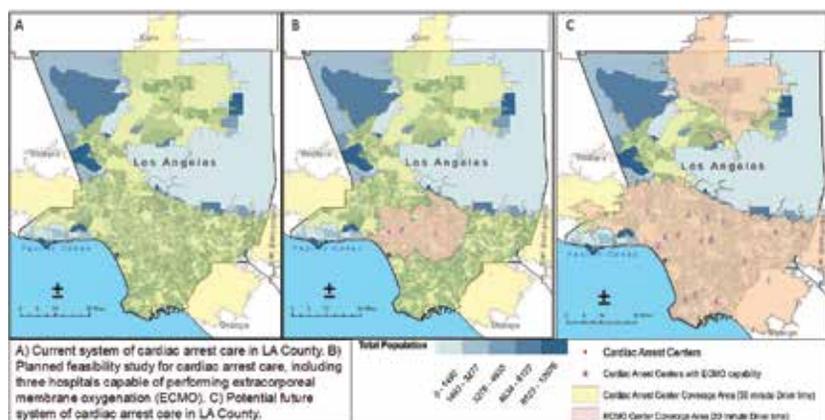
### IMPROVING OUTCOMES

There are ongoing efforts in LA County to improve outcomes from OHCA. The figure below shows the current, planned, and potential future systems for cardiac arrest care in LA County.

In the current regional system, over 99% of the LA County population has access to a cardiac arrest receiving center within a 30 minute transport, but few patients can reach an ECMO-capable center within the necessary time. (See Figure 1a.)

With the planned feasibility study, 40% of the population will be within reach of an ECMO-capable center. (See Figure 1b.)

Including all cardiac arrest centers with the potential to perform this therapy and who have expressed interest in providing emergent ECMO for patients with OHCA as part of a regional system of care, 97% of LA County citizens would be within 30 minutes of an ECMO-capable center. (See Figure 1c.)



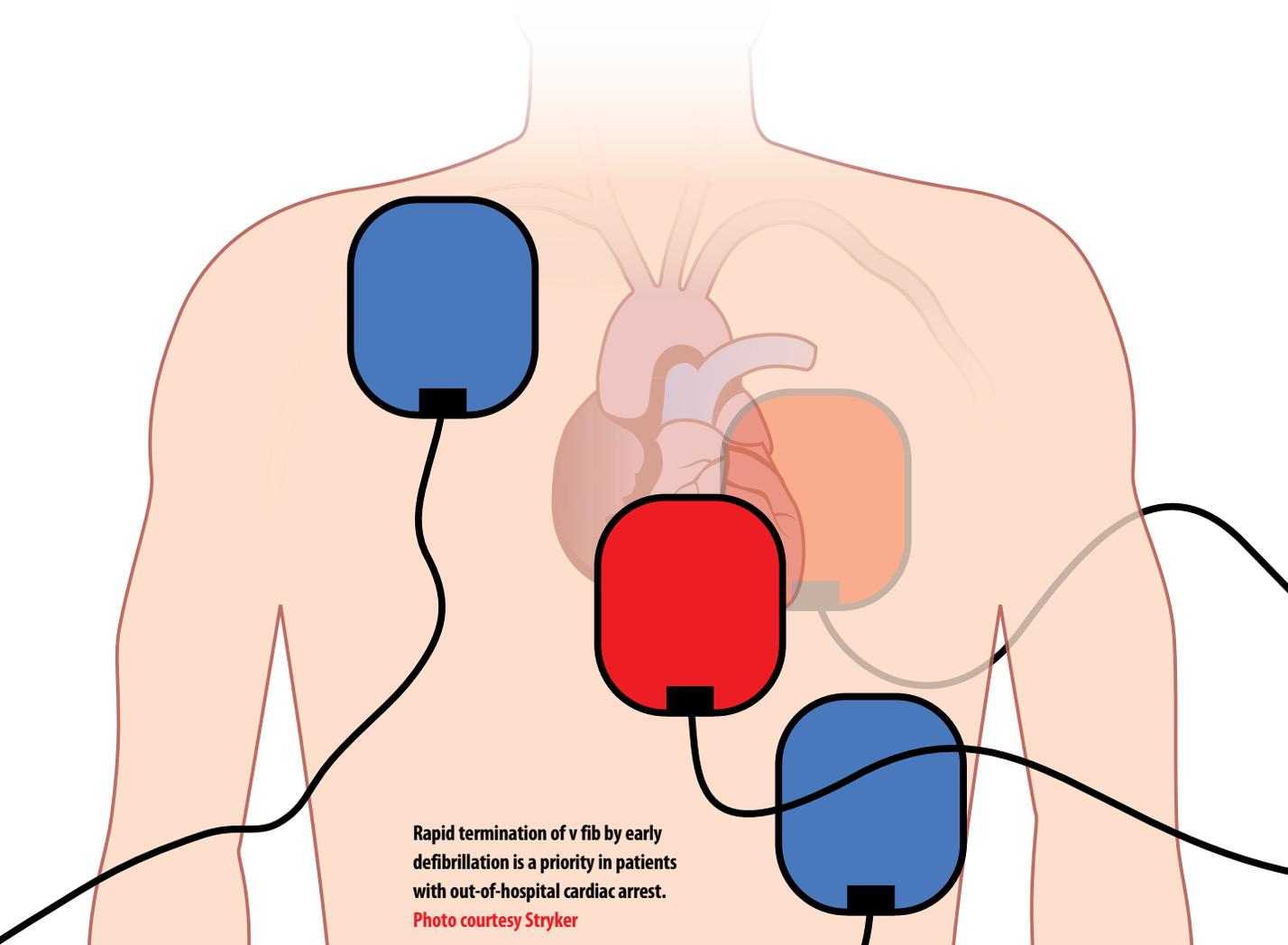
**Figure 1:** Current and future system of cardiac arrest care in Los Angeles County



**Nichole Bosson, MD, MPH, FAEMS**, is the assistant Medical Director for the LA County EMS Agency. She's also the EMS fellowship director and adjunct faculty in the Department of Emergency Medicine at Harbor-UCLA Medical Center in Los Angeles.

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Rapid termination of v fib by early defibrillation is a priority in patients with out-of-hospital cardiac arrest.

Photo courtesy Stryker

# THE EFFICACY OF DUAL SEQUENTIAL DEFIBRILLATION

## Despite successful case reports, evidence of improved outcomes still lacking

By Charles Deakin, MA, MD, MB BChir, FRCA, FRCP, FFICM, FERC

Approximately 20% of cardiac arrest patients present with ventricular fibrillation (v fib) as the initial rhythm.<sup>1</sup> Early defibrillation with conversion to an organized rhythm is associated with survival rates as high as 60%. Unfortunately, however, persistent and recurrent v fib are common. Prolonged v fib as a result of unsuccessful defibrillation correlates with poor rates of neurologically intact survival. As such, rapid termination of v fib is a priority.<sup>2</sup>

For patients with refractory v fib, treatment options are limited. CPR should be performed to optimize circulation which increases the likelihood of successful defibrillation. Once defibrillation energy has reached its maximum level, repeated shocks are indicated until v fib is terminated. The recommended defibrillation energy levels of 150–360 Joules are based on dose-response studies and are in a range where shock success is optimal but myocardial damage is minimal.<sup>3</sup>

Increasing the energy levels further may well terminate v fib, but risks myocardial injury manifesting as cardiogenic shock, hypotension and malignant arrhythmias, as well as conversion to terminal asystole.

*Increasing energy levels may terminate v fib but also risks myocardial injury.*

### WEIGHING THE EVIDENCE & RISKS

In an attempt to terminate refractory v fib, some clinicians have advocated the use of dual sequential defibrillation—using two defibrillators to each deliver two shocks nearly simultaneously, based on the assumption that more energy and/or a change in the defibrillation vector may be better. This usually involves the first pair of defibrillation pads being placed in a conventional antero-lateral position and the second pair being placed either alongside the first or in an antero-posterior position.

There are a few published case reports documenting “successful” dual sequential defibrillation that have driven adoption of this technique in the field, however, publication bias likely precludes case reports of unsuccessful attempts.

The most recent meta-analysis of dual sequential defibrillation found no association with an improvement in survival outcomes for patients with refractory v fib out-of-hospital cardiac arrest.<sup>4</sup> Large cohort studies published following this meta-analysis have also failed to demonstrate any benefit,<sup>5,6</sup> with one reporting that dual sequential defibrillation was actually associated with *lower* odds of prehospital return of spontaneous circulation (ROSC): 39.4% vs. 60.3%, adjusted OR 0.46 (95% CI: 0.25–0.87).<sup>7</sup>

Concern has also been raised that the use of two defibrillators discharged at the same time may risk one defibrillator damaging the other due to retrograde current flow. A recent case report using two defibrillators from two different manufacturers together reported subsequent malfunction of the latter due to the shortage of the printed circuit board assembly, prohibiting further defibrillation shocks from being delivered.

For these reasons, the routine use of dual sequential defibrillation in patients with refractory v fib can't be recommended at this time. A prospective randomized trial is underway that may provide further insight into the potential benefit or harm.

### MANAGING REFRACTORY V FIB

In any patient with refractory v fib, it's important to first ensure that oxygen delivery has been optimized, chest compressions are of good quality, and circulation has been optimized. Other considerations to remember:

- Avoid excessive doses of epinephrine which may drive ventricular arrhythmias.
- Ensure that defibrillation pads are correctly placed with the sternal pad placed below the right clavicle and to the right of the sternum and the apical pad being placed on the midaxillary line and

level with the V6 electrode position.

- Consider use of CPR adjuncts such as active compression-decompression CPR and the impedance threshold device, both of which provide higher levels of circulation during CPR than conventional CPR.<sup>8,9</sup>
- Ensure that two doses of amiodarone have been administered (300 mg IV and 150 mg IV).
- Consider the use of lidocaine (100mg IV) and/or esmolol (500 mcg/kg IV).



**Charles Deakin, MA, MD, MB BChir, FRCA, FRCP, FFICM, FERC**, is a consultant in cardiac anesthesia and cardiac intensive care at University Hospital Southampton and professor of resuscitation and prehospital emergency medicine at the University of Southampton. He's also the divisional medical

director of South Central Ambulance Service, clinical lead for the Hampshire & Isle of Wight Air Ambulance and Honorary Civilian Consultant Advisor in Pre-hospital Emergency Medicine to the British Army.

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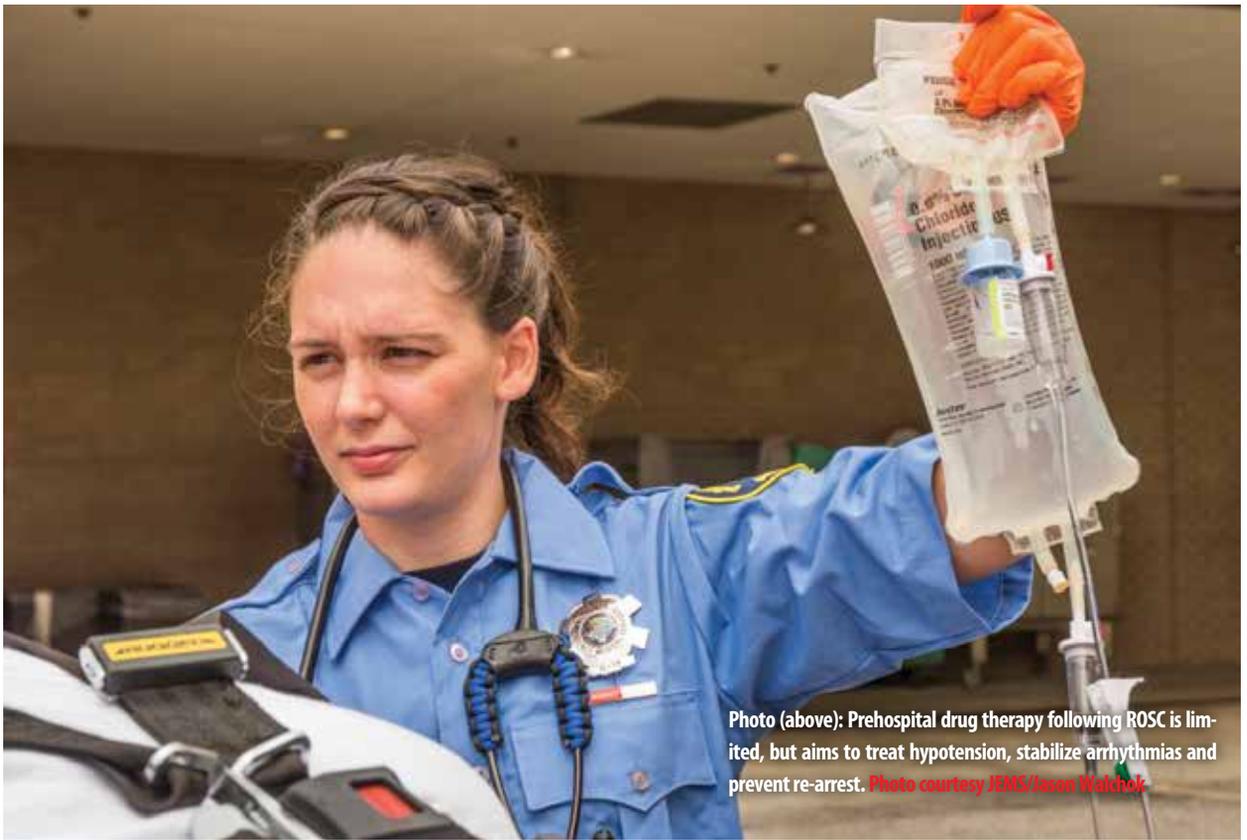


Photo (above): Prehospital drug therapy following ROSC is limited, but aims to treat hypotension, stabilize arrhythmias and prevent re-arrest. Photo courtesy ISMS/Jason Walchok

# DRUG THERAPY AFTER ROSC

## An overview of drug choices during resuscitation

By Charles Deakin, MA, MD, MB BChir, FRCA, FRCP, FFICM, FERC

Following initial resuscitation from cardiac arrest, patients are usually unstable—even more so following prolonged periods of resuscitation. Hypotension, arrhythmias and systemic vasodilation present significant challenges in patient management, and subsequently, there is a high rate of short-term mortality of patients with return of spontaneous circulation (ROSC). As many as 70% of patients admitted to hospital with ROSC won't survive.<sup>1</sup>

The challenges of dealing with these pathophysiological complications are compounded in the prehospital environment, where both pharmacological options and critical care interventions limit the ability to stabilize patients during what may often be prolonged transit times. Optimal post-resuscitation care, however, is key to neurologically intact survival, as recognized by the

final link in both European and North American chains of survival from cardiac arrest.

### MANAGING HYPOTENSION

Hypotension occurring during the first six hours after cardiac arrest is an independent predictor of poor one-year neurological outcome.<sup>2</sup>

A recent systematic review concluded that improved neurologic outcomes were associated with higher blood pressures in patients after cardiac arrest, either as an association between higher mean arterial pressure (MAP) and good neurologic outcome, or the presence of hypotension and increased mortality.<sup>3</sup> The optimal target blood pressure (BP) is unknown, but the value may well vary between patients depending on their normal BP.

Current guidelines recommend to immediately correct hypotension, which is defined as a systolic BP < 90 mmHg or MAP < 65 mmHg, during post-resuscitation care.<sup>4</sup> This is particularly important for neuroprotection, as cerebral autoregulation is lost, and cerebral blood flow is pressure dependent.

Hypotension results from a number of causes that need to be considered when optimizing therapy, but is primarily due to falling levels of epinephrine given during the cardiac arrest itself, cardiogenic shock secondary to global myocardial ischemia or stunning, and systemic vasodilation resulting from not only a global hypoxic injury to the smooth muscle of the vascular tree, but also a systemic inflammatory response.<sup>5</sup>

### OPTIMIZING HEMODYNAMIC MANAGEMENT

Hemodynamic management of these patients requires optimization in three sequential stages:

- 1. Filling:** The injured myocardium is less compliant than normal, pushing the Starling curve to the right and IV fluid boluses of 250 mL (given with caution) may therefore improve cardiac output considerably. Systemic vasodilation will also act to leave the patient relatively hypovolemic resulting in additional requirements for IV fluids.
- 2. Systemic vascular resistance (SVR):** The SVR may be low due to the post-cardiac arrest syndrome causing systemic vasodilation but may also be high due to the large amount of inotropes that have invariably been administered. The aim is to adjust the SVR to within the normal range; too low a value results in hypotension and poor capillary blood flow, but equally, too high a value results in systemic vasoconstriction with poor capillary blood flow together with a large afterload which precipitates further cardiogenic shock. Norepinephrine is primarily an alpha-agonist suitable as a first-line drug with which to control the SVR.
- 3. Inotropes:** If the patient remains hypotensive after optimizing filling and SVR, beta-agonists are indicated. Dopamine is a suitable initial beta-agonist, but if further drive is required, epinephrine may be necessary, despite its propensity to cause significant tachycardia. Contrary to European Resuscitation Council guidelines, dobutamine is rarely appropriate as a primary inotrope because its vasodilator properties compound the systemic vasodilation occurring from the inflammatory response, acting to worsen hypotension.<sup>6</sup>

Remember that the goal is to optimize blood flow—increasing the BP with a vasoconstrictor worsens flow and risks exacerbating cardiogenic shock, which is perhaps why inotropes haven't been shown to consistently improve outcome.

Physiological variables such as BP, heart rate, urine output (> 1 mg/kg/hr), lactate clearance, and central venous oxygen saturation are useful markers to guide therapy. In the ICU, an arterial line for continuous BP monitoring is essential and cardiac output monitoring may also help guide treatment.

Arrhythmias are also common following ROSC. Prompt anti-arrhythmic treatment may reduce the risk of re-arrest and improve hemodynamic stability. Amiodarone is recommended as the initial anti-arrhythmic (300 mg IV initial dose, followed by 150 mg IV second dose) but the addition of lidocaine (100 mg IV) may also be of benefit, particularly in specific circumstances, such as during EMS transport, when treatment of recurrent v fib or pulseless v tach might prove to be challenging.<sup>7,8</sup> The use of beta-blockers to terminate shock-refractory v fib (esmolol 500 mcg/kg IV loading dose, followed by a drip of 0–100 mcg/kg/min) should also be considered.

Prehospital drug therapy following ROSC is limited, but aims to treat hypotension, stabilize arrhythmias and prevent re-arrest. Optimize filling with careful boluses of 250 mL IV crystalloid boluses, administer 10–20 mcg boluses of epinephrine IV to maintain systolic BP > 80 mmHg and give lidocaine 100mg IV if the patient remains arrhythmic following two doses of amiodarone.



**Charles Deakin, MA, MD, MB Chir, FRCA, FRCP, FFCM, FERC**, is a consultant in cardiac anesthesia and cardiac intensive care at University Hospital Southampton, and professor of resuscitation and prehospital emergency medicine at the University of Southampton. He's also the divisional medical director of South Central Ambulance Service, clinical lead for the Hampshire & Isle of Wight Air Ambulance and Honorary Civilian Consultant Advisor in Prehospital Emergency Medicine to the British Army.

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# CARDIAC ARREST RECEIVING CENTERS

## Effective or trendy?

By Michael Jacobs, EMT-P

In 2005 a trauma surgeon, an ED doc, and a cardiologist published “Level 1 Cardiac Arrest Center, Learning from the Trauma Surgeons.”<sup>1</sup>

In 2006, a positive study was published from a National Evaluation of the Effect of Trauma Center Care on Mortality that showed the risk of death is significantly lower when care is provided in a trauma center than in a non-trauma center and argued for continued efforts at regionalization.<sup>2</sup>

Jump forward to 2015, the Institute of Medicine (IOM) report on cardiac arrest recommended Cardiac Arrest Receiving Centers.<sup>3</sup>

And in 2018, the American Heart Association (AHA) released a scientific statement regarding out-of-Hospital Cardiac Arrest (OHCA) Resuscitation Systems of Care.<sup>4</sup> This scientific statement recommended criteria for both level 1 receiving centers and level 2 referring centers as well as potential barriers within a receiving center to improvements in cardiac outcomes.<sup>4</sup>

A systematic review and meta-analysis published in a 2018 article published by the AHA concluded, “adult patients suffering from an out-of-hospital cardiac arrest transported to cardiac resuscitation centers have better outcomes than their counterparts do and when possible, it is reasonable to transport these patients directly to cardiac resuscitation centers.”<sup>5</sup>

About the same time, a publication endorsed by the American College of Emergency Physicians concluded, “both early inter-facility transfer to a cardiac arrest receiving center and direct transport to a cardiac arrest receiving center from the scene are independently associated with reduced mortality.”<sup>6</sup>

Despite progress in this area, today there are still too many variations in post-resuscitation cardiac arrest care. In California, only two of 33 California Local Emergency Medical Services Agencies (LEMSA) provide region-specific care after OHCA.

Although many patients can be taken to

PCI-capable hospitals for primary percutaneous coronary intervention (PCI) and targeted temperature management post arrest, there is limited regional coordination and system quality improvement. Only one-third of LEMSAs have access to hospital data for patient outcomes. Alameda County Emergency Medical Services (ALCO EMS) is one of the two LEMSAs referred to in this study.<sup>7</sup>

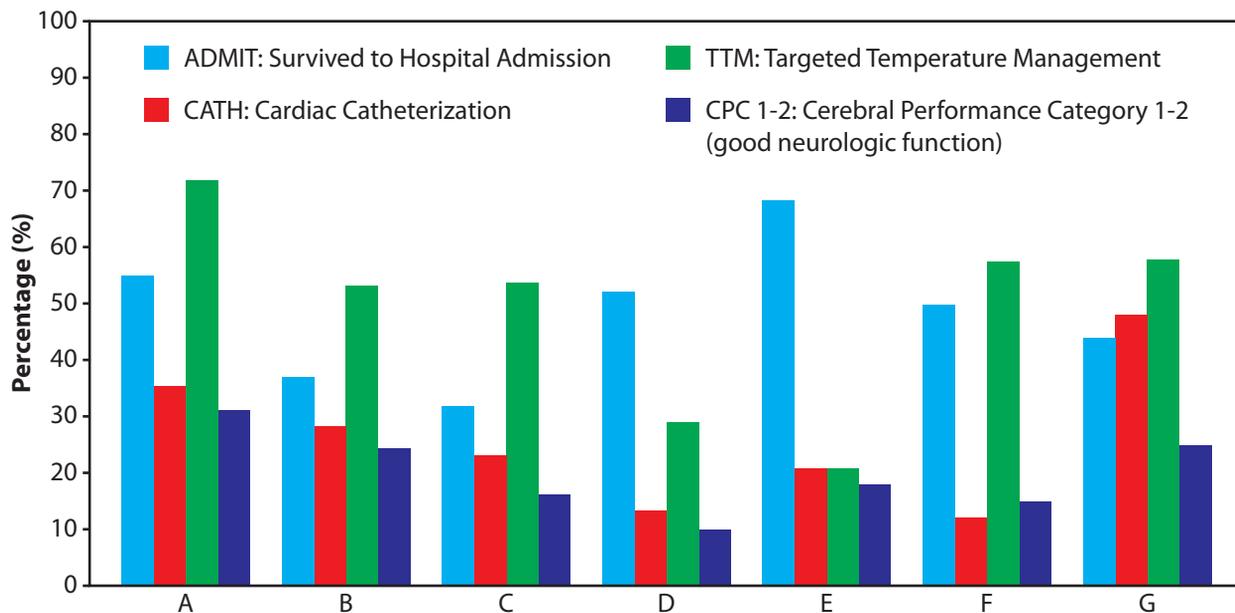
In 2013 ALCO EMS served a population 1.6 million with 1,100 OHCA annually. At that time six of 12 hospitals were ST-elevation myocardial infarction (STEMI) receiving center systems. There are now seven. All provide therapeutic hypothermia experience for comatose OHCA patients who have had a return of spontaneous circulation (ROSC).

These hospitals are now also designated as cardiac arrest receiving centers. EMS field protocol directs patient transport to these centers if ROSC or a shockable cardiac rhythm is achieved at any time. This model allows patients to be transported to a facility that has the capability of and experience in 24/7 emergent cardiac catheterization, targeted temperature management, metabolic support, circulatory support and neuro-prognostication in the ICU. These specialty centers also offer electrophysiology, rehabilitation, organ procurement and psychologic support services for both patient and family following OHCA. (Examples of EMS OHCA resuscitation and post-ROSC protocols from Alameda County, Calif. can be found at <http://ems.acgov.org>.)

ALCO EMS established contractual agreement by memorandum of understanding (MOU) with every participating cardiac arrest center. This has fostered an instrumental collaboration with system stakeholders regarding ongoing review and revisions of prehospital protocols, as well as in-hospital order sets and treatment pathways based on current scientific evidence.



Professional relationships are pivotal to help ensure continuity of care from dispatch to discharge.



**Figure 1: Variability among seven cardiac arrest receiving centers (A-G). Admission, interventions and outcomes for transported OHCA Patients within a Regional EMS system in 2018.**

These continued professional relationships are pivotal to help ensure the continuity of care from dispatch to discharge. Yet even with processes in place and contractual stakeholder commitment, the variability in center admission, performance and patient outcomes still exists. (See Figure 1.)

In 2019, the variability in survival and post-cardiac arrest care following successful resuscitation from OHCA was investigated by Balian and colleagues and they concluded, “Hospital case volume is associated with improved patient outcomes. Inter-hospital variability in OHCA outcomes may potentially be addressed by regionalization of care to high volume centers with higher rates of post-arrest care provision and better patient outcomes.”<sup>8</sup>

Without institutional standardization of treatment pathways, inclusion/exclusion criteria for interventions, order sets and neuro-prognostication within a single cardiac arrest receiving center, the concept of regionalized systems of care for OHCA will not be possible. Unfortunately, individual provider experience, bias and preconception will continue to foster variability in care.

Moreover, until a champion(s) within one institution can minimize variability

and improve continuity of care across the multi-disciplinary spectrum of emergency medicine, cardiology and critical care by standardization and accountability within their own facility, the idea of a regional consortium/collaborative will be difficult to achieve.

This may be a great opportunity for the LEMSAs to get local receiving centers together to discuss and compare practices, performance and outcomes as well as develop consensus for regional adoption and standardization.

Recognizing that not all cardiac arrests and presenting situations are equal, at minimum, patients suffering witnessed OHCA should *all* have the same opportunities for timely treatment and every chance for neurologically intact survival if possible, regardless of EMS system, hospital, region, state or even country! Imagine ... maybe someday?



**Michael Jacobs, EMT-P**, is a paramedic and coordinator of specialty systems of care with Alameda County (Calif.) EMS and Health Care Services Agency.

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The asystolic organ donor program has resulted in a significant increase in the number of organs donated annually in Madrid, Spain. Photo courtesy SAMUR Civil Protection

## In Madrid, Spain, patients presenting in asystole may become organ donors

By Ervigio Corral Torres, MD

In 1996, SAMUR Civil Protection—the EMS service for the city of Madrid, Spain—and the San Carlos Clinical Hospital implemented the world’s first organ donation protocol for donors with uncontrolled asystole due to unsuccessful resuscitation. (Non-heart beating donors are grouped by the Maastricht classification, and this is known as Maastricht Type-2.) At that time, Spanish law did not accommodate organ donations associated with patients who present with asystole, and it wasn’t until years later that a law was passed to allow for it.

The organ donation protocol has patient inclusion and exclusion criteria which has evolved over time. Today, potential donors must be within the range of 7–55 years old and must have suffered a witnessed cardiac arrest with an initial rhythm of asystole, which can be due to a medical or traumatic cause. The protocol is also time dependent. (See Figure 1.)

Patients with signs of drug addiction, abdominal and thoracic traumas, and morbid obesity are excluded.

### PROCEDURE LOGISTICS

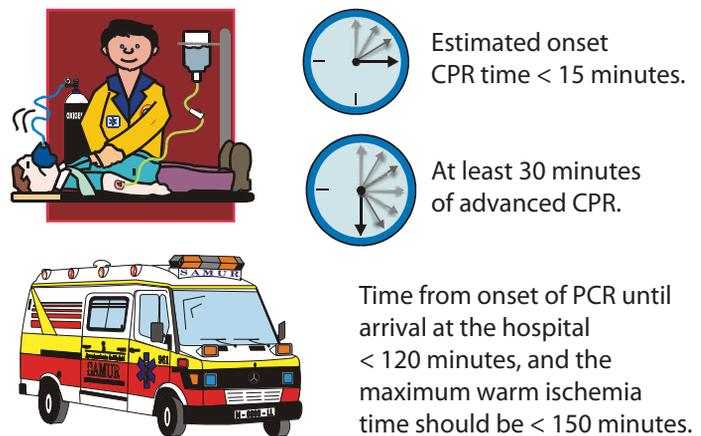
When there’s a possibility of an asystolic organ donor, the hospital transplant coordinator is immediately contacted. This person is, without doubt, the key to the success of the entire Spanish organ transplant model. Simultaneously, the SAMUR Communications Center activates the rest of the procedure participants: the local and national police, as well as the hospital emergency department and ICU.

From that moment, the patient no longer has a “condition” and is identified as the “donor.” Medics stop administering drugs, begin use of maintenance fluids and transport the donor to the hospital with ongoing chest compressions.

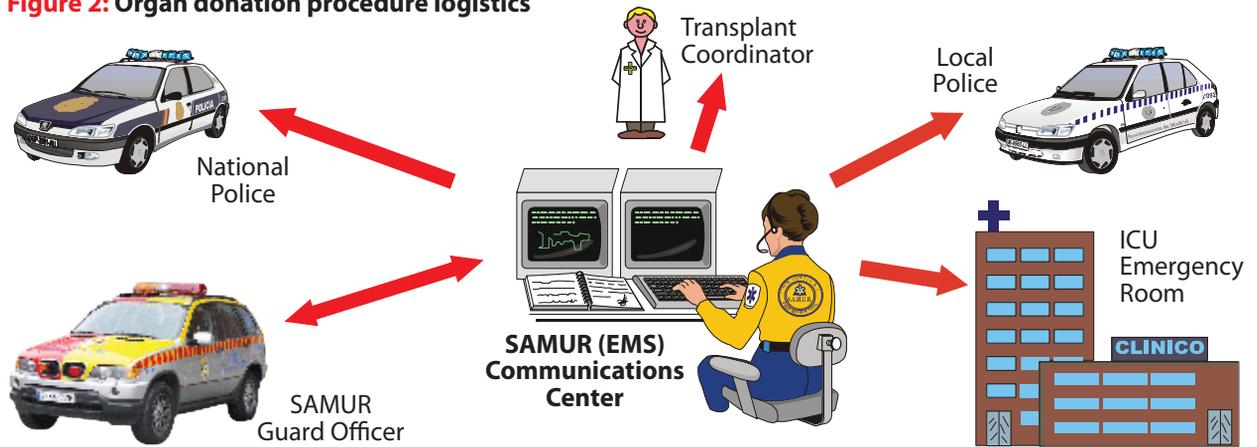
Police escort the SAMUR ambulance to the hospital, maintaining a constant speed. At the same time, the national police locate the family, as consent for the donation is necessary.

The process is rigorous. The donor must be declared dead by a doctor who’s not the transplant coordinator—this is according

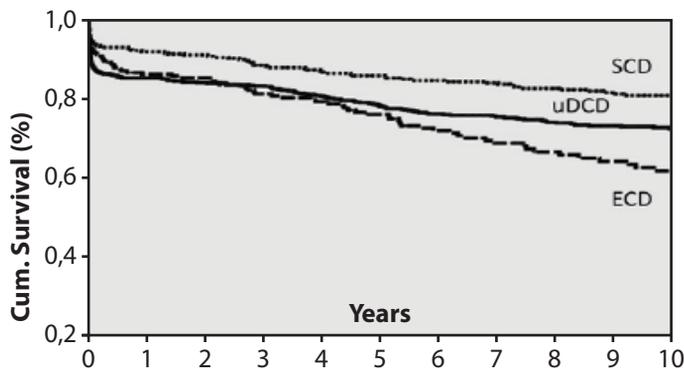
**Figure 1: Criteria for inclusion in organ donation procedure**



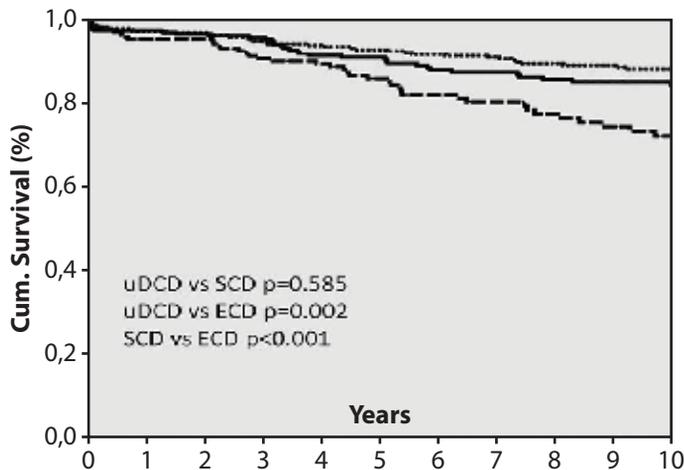
**Figure 2: Organ donation procedure logistics**



**Figure 3: Success (10 years) of post-death kidney donation**



At risk	1 year	3 years	5 years	7 years	10 years
uDCD	639	587	485	389	277
SCD	331	304	282	255	197
FCD	199	166	133	100	68



At risk	1 year	5 years	10 years
uDCD	226	177	106
SCD	282	244	174
FCD	160	108	58

Sánchez-Fructuoso AI, Pérez-Flores I, Del Río F, et al. Uncontrolled donation after circulatory death: A cohort study of data from a long-standing deceased-donor kidney transplantation program. *Am J Transplant.* 2019;19(6):1693–1707. DOI: 10.1111/ajt.15243

to procedure. Then, the transplant coordinator must inform a judge on duty. The judge conducts the interview with the family to obtain the donation.

It takes an average of 76 minutes from the beginning of CPR until hospital arrival, and then another 43 minutes to cannulate and connect the patient to ECMO. The average time of “hot ischemia”—the most important time for organ survival—is 120 minutes.

**SUCCESS RATE**

We compared kidney transplant viability among brain death donors with strict criteria, SCA uncontrolled donors, and those of brain death with extended criteria.

The long-term functionality of the kidneys from asystolic patients in the protocol was very similar to that of donors with strict criteria of brain death.

Overall, the asystolic organ donor program has resulted in a very significant increase in the number of organs donated per year in our city.

**CONCLUSION**

It is our opinion that the Maastricht Type 2 uncontrolled organ donor classification is a good alternative source of organs, which can be added to the other sources for organ donors.

It’s important to emphasize that the viability of the asystolic Maastricht Type 2 patient population continues to be evaluated as someday it may be possible to successfully resuscitate this patient population. The organ donor program would then need to be modified accordingly.



**Ervigio Corral Torres, MD**, is the head of training and research department at SAMUR Civil Protection, the local EMS service for the city of Madrid, Spain.



The use of ECMO in trauma is becoming more popular in recent years. Photo courtesy Magnus Larsson

# EXTRACORPOREAL MEMBRANE OXYGENATION IN TRAUMA

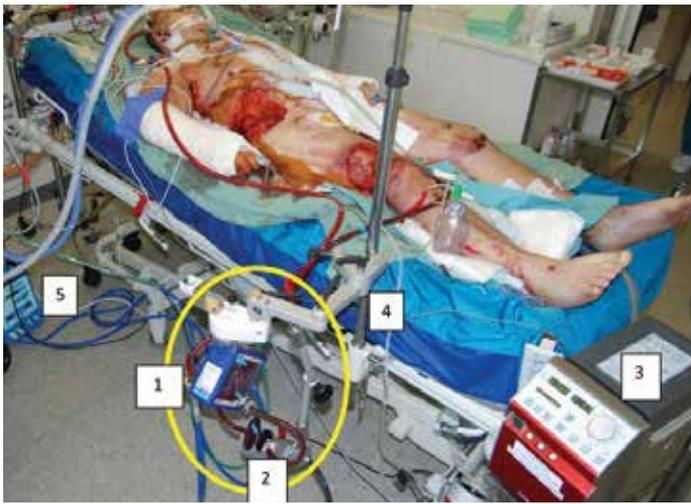
**Long regarded as a contraindication, there may be value in using ECMO for trauma patients**

By Pål Morberg, MD

**E**xtracorporeal membrane oxygenation (ECMO) is a mechanical method of supporting the heart and lungs in critically ill patients that dates to the 1970s. A hollow fiber membrane lung is used to oxygenate venous blood extracted from the central venous compartment. It's then pumped back into the aorta—venoarterial (VA) ECMO—or to the larger veins—venovenous (VV) ECMO. It also can be pumped back to both the venous and arterial side—venoarterial (VVA) ECMO. (See Figure 1.)

Trauma was long regarded as a contraindication for ECMO, however, this is changing. A

recent study of data from the Extracorporeal Life Support Organization (ELSO) Registry showed that 279 trauma patients were offered ECMO support out of approximately 30,000 ECMO patients between 1989 and 2017.<sup>1</sup> Patients were included in the study days seven days after admission to the ICU. Of the patients looked at in the study, 89% had VV ECMO support, 7% had VA ECMO support, and 4% received ECMO assisted cardiopulmonary resuscitation (ECPR).<sup>1</sup> Although the study went all the way back to 1989, half of all registered patients in the study received ECMO after 2009, indicating an increase in the frequency ECMO use in more recent years. Over time, survival has increased and indications broadened, suggesting that the suitable patient for ECMO has become less elusive for clinicians.



ECMO is a mechanical method of circulating and oxygenating blood via a 1) membrane oxygenator; 2) centrifugal pump; 3) rotaflow controller; and 5) heat exchanger. **Figure** courtesy Magnus Larsson

### DEFINING TRAUMA

In the scientific and medical literature, the definition of trauma is not uniform. Some studies limit themselves to strictly mechanical trauma, excluding trauma due to thermal, electrical and chemical injuries, or hanging, drowning, strangulation, hypothermia and poisoning. Others may include a few or more of these types.<sup>2-4</sup> Different classifications are understandable as the definitive treatment may vary.

On the other hand, any of these traumatic injuries would be handled by EMS with a similar level of urgency.

Causes of trauma injury are categorized in the same chapter of the International Statistical Classification of Diseases and Related Health Problems (ICD) under ICD-10 codes V01-Y98.

If drowning and poisoning were included as items of trauma in the ELSO Registry, outcome data might look different as the effect on survival and number of ECMO trauma patients would change.

### TRAUMA PHYSIOLOGY

Hypothermia, coagulopathy and acidosis has been regarded as important factors contributing to overall mortality from trauma. ECMO support offers a way to counteract and reverse their development.

Hypothermia, the result of paucity of thalamic temperature regulation, may increase oxygen demand severalfold, aiming to keep temperature homeostasis.<sup>5</sup> The increase in lactic acid and shift to anaerobic metabolism decrease pH, which augments trauma coagulopathy. ECMO provides circulatory support in case of shock. Effective temperature control and stabilization of physiology has been seen in animal studies compared to standard resuscitation efforts.<sup>6,7</sup>

Furthermore, VA ECMO reduces central venous

pressure contributing to reduced risk of venous bleedings. Moreover, the ECMO circuit offers an unsurpassable delivery system for tempered blood products.<sup>6,7</sup>

Lastly, ECMO may offer solutions to otherwise surgically very challenging situations such as bronchial damage,<sup>8</sup> air-leak syndrome, severe lung bleedings, and management of development of over-transfusion syndrome with critical lung failure.

### CONSIDERATIONS

The use of ECMO in trauma requires a longitudinal system from assessment and initiation to ICU and long-term follow-up. VV ECMO was by far the most used modality.<sup>1</sup>

The role of ECMO in hemorrhagic shock is not clear but animal studies and case reports suggest an additional benefit of VA ECMO in the right patient.<sup>6,7,9</sup>



**Pål Morberg, MD**, is anaesthesia registrar at the University Hospital of North Norway in Tromsø.

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# REBOA & SAAP IN POST-TRAUMATIC CARDIAC ARREST

## Endovascular hemorrhage control & extracorporeal resuscitation techniques continue to evolve

By James E. Manning, MD

**T**he past decade has seen the rise of endovascular hemorrhage control in clinical trauma care.

### RESUSCITATIVE ENDOVASCULAR BALLOON OCCLUSION OF THE AORTA (REBOA)

Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) has become an established intervention for the management of non-compressible torso hemorrhage below the level of the diaphragm.

If the site of ongoing hemorrhage below the diaphragm is unclear, balloon occlusion at the level of the thoracic aorta (Zone 1) is recommended, whereas, if site of bleeding is clearly isolated to the pelvic region, balloon occlusion at the level of the infrarenal aorta (Zone 3) is appropriate. There are now numerous laboratory studies, case reports, and case series from databases that support the use of REBOA in trauma.

Although there's some debate over inclusion criteria for the use of REBOA, the available evidence supports the position that REBOA can limit arterial hemorrhage, support mean arterial pressure (MAP) and extend survival in trauma patients with non-compressible torso hemorrhage and hypotension unresponsive to initial fluid and blood resuscitation.

The value of REBOA is greatest when used early in trauma resuscitation prior to cardiac arrest. The immediate hemodynamic effects of REBOA include limiting ongoing arterial hemorrhage below the level of the aortic balloon occlusion and increased systemic vascular resistance (SVR) that supports MAP above the balloon.

Both effects serve to "buy time" for intravenous volume resuscitation with blood products and transfer to a hospital for definitive surgical hemostasis. In a cardiac arrest state, Zone 1

REBOA is indicated to maximize the hemodynamic effects.

Although distal arterial hemorrhage control is achieved by aortic balloon occlusion, but the beneficial effect on MAP is largely lost because a beating heart is needed as a driving force for blood flow to load and pressurize the thoracic aorta.

Thus, REBOA in cardiac arrest requires closed-chest CPR to generate blood flow to increase proximal MAP, and CPR has been shown to be less effective in the setting of hemorrhage-induced hypovolemia.

The use of REBOA in post-traumatic cardiac arrest has also been described but remains controversial. One of the factors that clouds this issue is how we define cardiac arrest in trauma patients. Strictly speaking, the term "cardiac arrest" means the "heart" has "stopped beating."

However, in clinical practice traumatic cardiac arrest is generally considered a loss of pulses or inability to discern a systolic blood pressure. This typically means having a systolic blood pressure less than 30–40 mmHg which is the lowest blood pressure that can be detected by non-invasive means under optimal conditions.

If there's still an organized ECG rhythm, this defines a state of pulseless electrical activity (PEA) and may be associated with no cardiac contractility or some residual cardiac contractility without discernible blood pressure or pulses (described as pseudo-EMD). The distinction between EMD and pseudo-EMD has been largely disregarded because they have been treated the same under ACLS algorithms.

Although clinical outcome data are currently lacking, this distinction may be quite important in endovascular treatment of hemorrhage-induced traumatic cardiac arrest.

Trauma patients with profound hypotension

but a beating heart, which is a state of “impending cardiac arrest,” may be more responsive to REBOA than patients in whom there is no cardiac contractility to pressurize the aorta, which is a “true cardiac arrest” state.

In impending cardiac arrest (as defined here), REBOA may allow the heart that is still beating to increase the arterial blood pressure enough to circulate transfused blood resulting in restoration of central arterial blood volume, improved coronary perfusion, and reversal of the spiral toward true cardiac arrest provided that the REBOA catheter can be inserted and the balloon inflated before the patient actually decompensates into a true cardiac arrest.<sup>1</sup> Clinical outcomes are needed to confirm these hypotheses.

Clinical case series indicate that some patients with post-traumatic cardiac arrest are responsive to REBOA.<sup>2</sup>

The AORTA Study has shown REBOA to be at least equally effective to resuscitative thoracotomy for achieving survival with lower morbidity and less rehabilitation required.<sup>3</sup> However, clinical reports to date haven't made a clear distinction between patients with a beating versus a non-beating heart.

Understandably, this isn't easy to determine without invasive pressure monitoring or careful ultrasound examination of the heart, both being problematic during active resuscitation.<sup>4</sup>

For data collection and reporting purposes, patients in a clinical cardiac arrest state with no discernible blood pressure are assigned values of “0 mmHg,” and this is also problematic since some of these patients may have actually had blood pressures as high as 30–40 mmHg that simply couldn't be detected.<sup>5</sup>

However, many clinical practitioners with substantial experience using REBOA in trauma have noted that patients with complete loss of cardiac activity (i.e., true cardiac arrest) have much worse outcomes than those that still have a beating heart (i.e., impending cardiac arrest).<sup>6</sup>

In a recent consensus document, practitioners using REBOA in trauma resuscitation had mixed opinions, but this expert panel didn't recommend REBOA for patients in extremis, defined as no discernible blood pressure or pulses.<sup>7</sup>

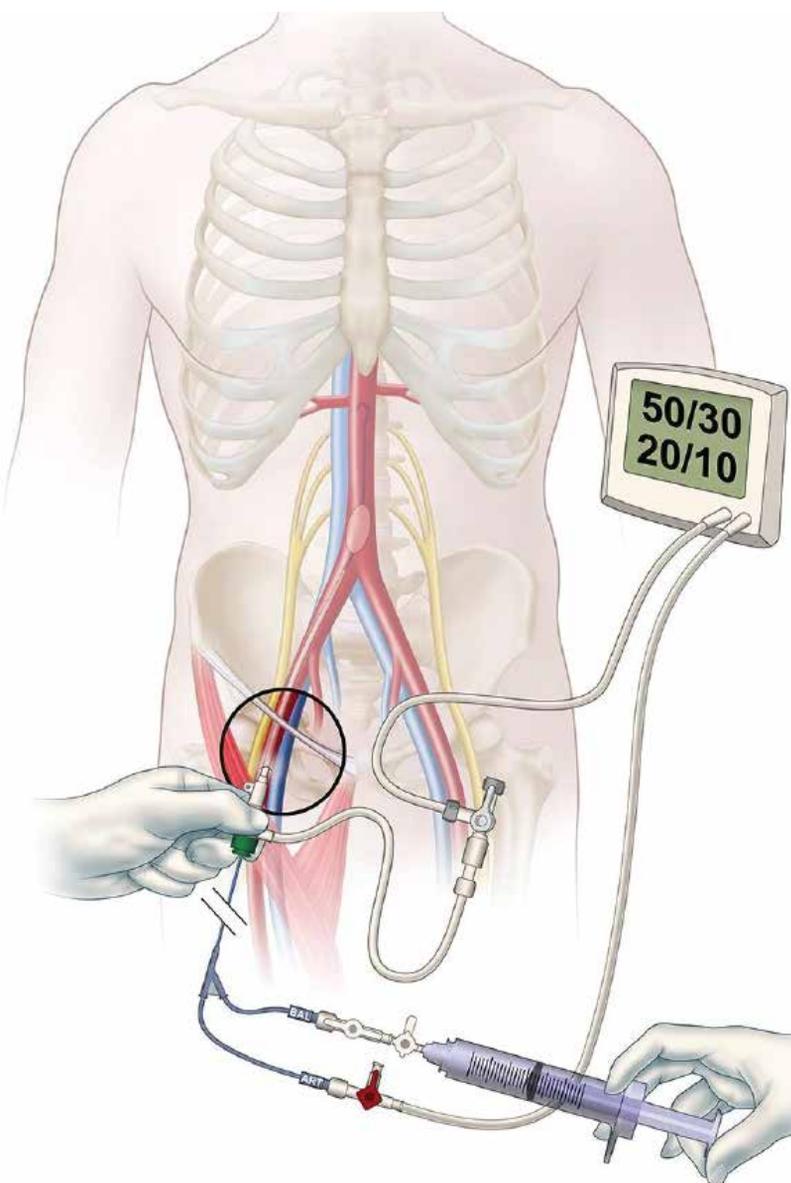
This isn't to say that a trauma patient in true cardiac arrest cannot be resuscitated with REBOA in combination with closed-chest CPR, IV blood transfusion and other interventions, but the chances of reversing true cardiac arrest with REBOA are very limited.

Little is known at present if CPR adjuncts that provide increased circulation, such as use of active compression-decompression CPR and the impedance threshold device will be synergistic with REBOA. In addition, another clinical challenge is rapidly and accurately determining which patients are in true cardiac arrest versus impending cardiac arrest.

### SELECTIVE AORTIC ARCH PERFUSION

Selective aortic arch perfusion (SAAP) is another resuscitation technique specifically developed to treat cardiac arrest and that may offer benefit in resuscitation of hemorrhage-induced traumatic cardiac arrest.<sup>8</sup>

However, there have been no clinical trials with SAAP in patients in cardiac arrest at the current time.



**Balloon catheter insertion and inflation (with proximal and distal blood pressure measurement). Photo courtesy UK-REBOA Trial Protocol**

SAAP uses a large-lumen balloon occlusion catheter inserted into the thoracic aorta to provide relatively isolated perfusion to the heart and brain during cardiac arrest. Unlike REBOA, SAAP is primarily an extracorporeal perfusion technique. In this regard, it functions more like brief extracorporeal membrane oxygenation (ECMO) than REBOA.<sup>9</sup>

However, in trauma cardiac arrest with non-compressible torso hemorrhage, SAAP does also provide for arterial hemorrhage control below the diaphragm and rapid restoration of lost intravascular blood volume. SAAP provides heart and brain perfusion support to promote ROSC and may not require closed-chest CPR.<sup>9</sup>

SAAP begins with an exogenous oxygen carrier (e.g., whole blood, packed red blood cells, or polymerized hemoglobin) to restore intravascular and can be transitioned to partial or full-body ECMO support, if needed. Thus, SAAP has potential utility in treating both true and impending cardiac arrest as a result of severe traumatic hemorrhage.<sup>10</sup>

The use of endovascular resuscitation techniques, such as REBOA and SAAP, is in its infancy for the treatment of cardiac arrest. Such techniques can both stabilize trauma patients to avoid deterioration to cardiac arrest and promote ROSC when cardiac arrest has occurred.

Differentiating impending cardiac arrest with a beating heart vs. true cardiac arrest with a non-beating heart will likely be an important factor as decision algorithms are developed to guide the use of these more advanced endovascular hemorrhage control and extracorporeal resuscitation techniques.



**James E. Manning, MD**, is professor of emergency medicine at the University of North Carolina at Chapel Hill School of Medicine. He is also the co-founder and the chief medical officer of Resusitech.

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*Many clinical practitioners with substantial experience using REBOA in trauma have noted that patients with complete loss of cardiac activity have much worse outcomes than those that still have a beating heart.*

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# IMPLANTABLE DEFIBRILLATORS AFTER CARDIAC ARREST

## Despite successful case reports, evidence of improved outcomes still lacking

By Keith G. Lurie, MD

**I**t's always wonderful when a person has been resuscitated after sudden cardiac arrest (SCA). Our challenge, as clinicians, is to keep such patients alive for a long time thereafter.

The 1990s heralded the new age of implantable cardioverter defibrillators (ICDs). These implantable computer-driven shock boxes have become smarter and smaller over the ensuing decades. Hundreds of thousands are implanted annually. ICDs are often indicated in patients with SCA but they aren't used. Many SCA patients are at risk for another cardiac arrest. Those at the highest risk need an ICD or they will inevitably have another event and die.

There are two different types of ICDs. (See Figure 1.) One is implanted in the left pectoral region and has leads within the heart to sense cardiac electrical activity and pace and/or shock the heart, as needed. A second type is placed subcutaneously and is used to sense the heart and then only to shock, as needed.

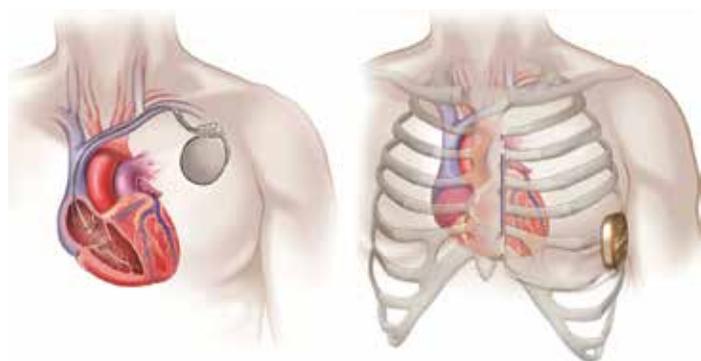


Figure 1: Two types of ICDs

ICD functionality can be summarized as follows:

- **Most basic:** Sense and shock v tach/v fib;
- **Basic:** Sense and shock v tach/v fib, pace the right ventricle;
- **More advanced:** Sense and shock v tach/v fib, pace the right atrium and right ventricle; and
- **Most advanced:** Sense and pace atrium and right and left ventricle, and shock v tach/v fib;

### HOW DO ICDs WORK?

1. Atrial and ventricular electrical activity is sensed.
2. An internal computer determines if detected impulses are normal.
3. If abnormal, the ICD may pace 1 to 3 cardiac chambers, charge the capacitors, over-drive pace terminates an arrhythmia, and/or deliver one or more shocks (1 Joule to up to 40 Joules).

ICDs are programmable depending upon the needs. For example, they can be programmed to pace the heart in a certain way, detect certain arrhythmias, and overtime pace-terminate or shock accordingly.

Figure 2a shows v fib treated with a shock.

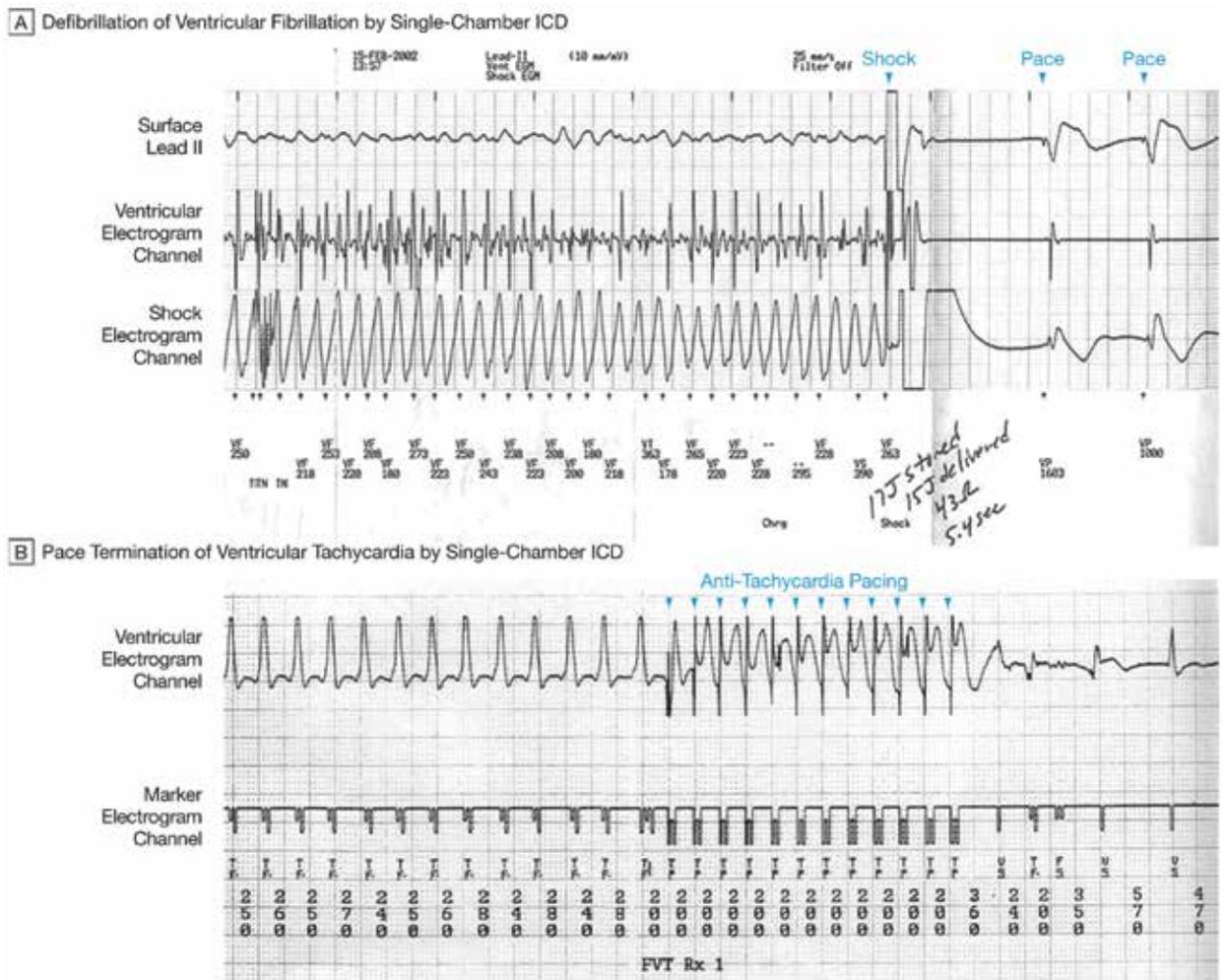
Figure 2b shows v tach treated with so-called overdrive termination, where the ICD pacing senses the v tach and paces the right ventricle at a faster rate for a brief period of time. This interrupts the v tach reentrant arrhythmia and a stable rhythm is restored.

### WHY IMPLANT ICDs?

If the patient is known to have a reasonably high likelihood of a life-threatening rhythm in the next year or more, an ICD is used as primary prevention. Examples of this include:

- Low left ventricular ejection fraction due to coronary artery disease;
- Inoperable severe coronary artery disease with inducible v tach; and
- Strong family history of long QT syndrome and SCA in siblings.

If the patient has had a life-threatening arrhythmia or a history of SCA, an ICD may be needed as



**Figure 2:** Examples of what ICD senses when there's life-threatening arrhythmia and how it's treated

part of a secondary prevention strategy due to the increased likelihood of a recurrent life-threatening arrhythmia. Examples of this include:

- History of SCA and successful resuscitation but persistently low ejection fraction; and
- History of SCA and successful resuscitation with severe coronary artery disease with only partial revascularization.

As an electrophysiologist, I'm on the aggressive side when it comes to placing an ICD. For me, it's straightforward: If the cause of the SCA was not reversible, an ICD should be placed.

But what about the cases that fall in between the black and white zones? These are more common than you might think. Here are some of the controversies as I see them:

- Need for antiarrhythmic agents that by themselves can be pro-arrhythmic;
- Patients with *no* history of angina and who have silent ischemia and a defective waning system, especially those with diabetes;
- Patients with known risk factors (e.g., diabetes,

hypertension, familial hypercholesterolemia, obesity) who can't be easily reversed with progression of coronary artery disease;

- Patients with coronary artery disease who were "fixed" but are at risk for restenosis (i.e., almost everyone; restenosis rates vary from 5% to > 10% annually.

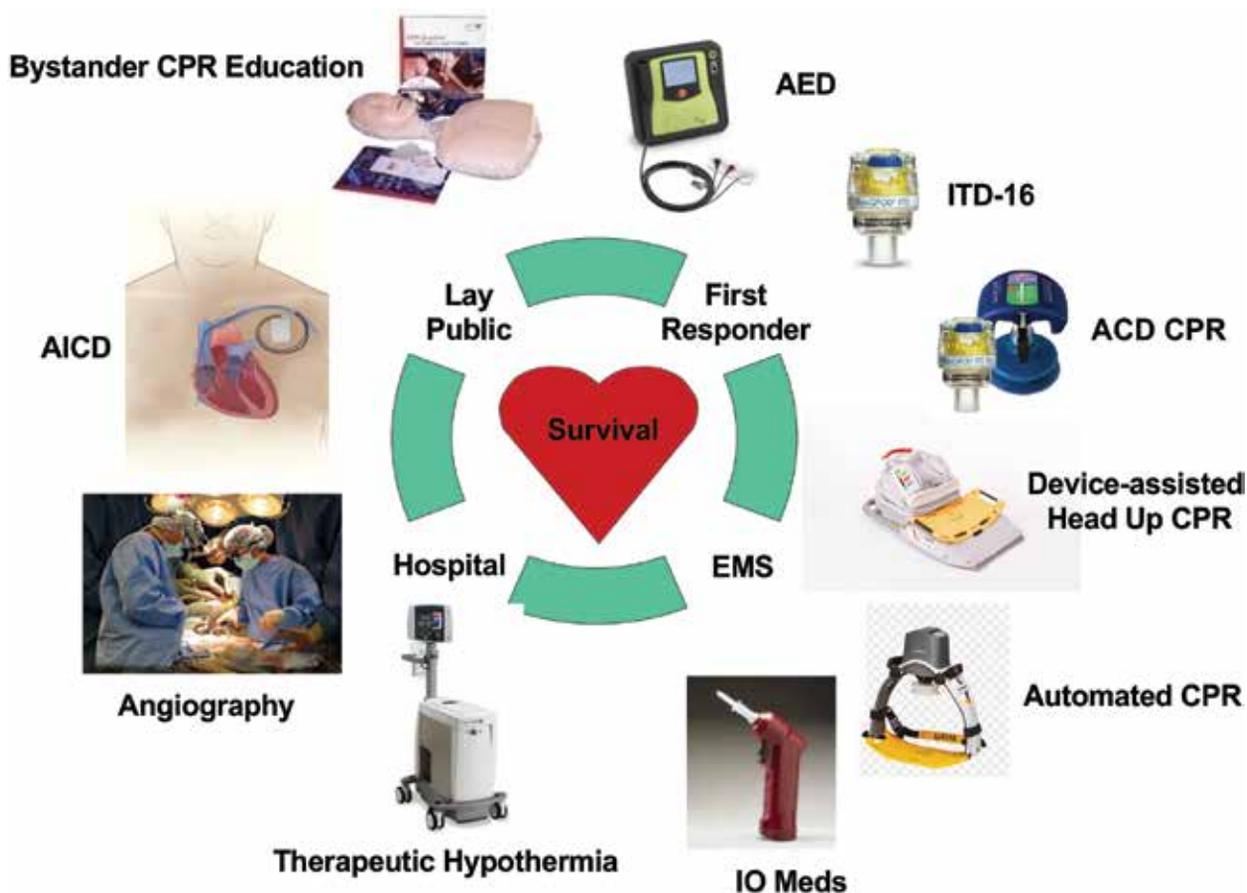
It's important to have a discussion with your patients about the risks and benefits of ICD therapy. Medical and ethical challenges can often arise.

For example, what should we recommend when someone is a truck driver and has indications for an ICD, but who will lose the ability to be issued a driver's license for a commercial vehicle in many states if they have an ICD?

When that patient doesn't get an ICD; that patient and the public are at risk. But how much risk? It's often hard to know. Without having a frank syncopal episode such patients can often legally drive.

There are additional controversies. Some, including me, feel there should be additional indications for ICD implantation.<sup>1</sup> Those indications should include:

1. Low ejection fraction at any time after a heart attack (< 35% improving to > 35%) was not associated with a decrease in lethal arrhythmia in a large clinical trial, and thus such patients should receive an ICD. In that study, ICDs protected equally well with



**Figure 3: Comprehensive cardiac arrest bundle of care**

- < 35% and > 35% ejection fraction due to myocardial infarction
- 2. In patients with a prior myocardial infarction, congestive heart failure but not ischemia was associated with a marked increase in SCA, thus such patients should receive an ICD.

**NEGATIVE ASPECTS OF ICDs**

- Infection < 2%.
- Unnecessary shocks from sensing supraventricular tachycardia, although this is much improved with better sensing technologies.
- Psychological stress: PTSD from multiple shocks is generally short-lived, and we must always consider the alternative; however, we are occasionally asked to turn off the ICD shock capability.
- Device failure: Leads can fracture over time and need to be replaced and very rarely the generator itself has a failure.

**RECURRENT SCA IS COMMON**

Recurrent SCA is common, and the likelihood of another cardiac arrest can be reduced by:

- correcting the underlying cause of the arrest (e.g., revascularization);
- reducing or eliminating risk factors (e.g., ETOH); and
- ICD implantation when v tach/v fib is the etiology or may be the etiology.

Importantly, most ICDs can also be used to pace for slow and fast heart rate abnormalities. Thus, they provide multiple therapies that are often required for long-term survival and a high quality of life.

**CONCLUSION**

In summary, we must remember that our patients already died once. ICDs can provide protection against another SCA event. Use of ICDs are part of the comprehensive bundle of care that forms the core of the therapy described by the International State of the Future of Resuscitation Collaboration. (See Figure 3.) ICDs should be seriously considered for every patient who’s successfully resuscitated from SCA.



**Keith G. Lurie, MD**, is a cardiologist in St. Cloud, Minn. He’s the inventor of the ResQPOD and the ResQPUMP, as well as other medical devices, including gravity-assisted CPR devices. He’s also a professor of internal and emergency medicine at University of Minnesota, Minneapolis, and continues to work on advancing the science of cardiopulmonary resuscitation.

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# EXTRACORPOREAL CARDIOPULMONARY RESUSCITATION IN THE CARDIAC CATHETERIZATION LABORATORY

## Timely ECPR provides substantial survival benefit in patients suffering cardiac arrest

By Ganesh Raveendran, MD, MS;

Jason A. Bartos, MD, PhD &

Demetris Yannopoulos, MD

**T**here are approximately 400,000 cases of out-of-hospital cardiac arrest in the United States every year.<sup>1,2</sup> Of those, between 40% and 60% are refractory (i.e., unmanageable or unresponsive) to the available resuscitation therapies leading to very high mortality in these patients.<sup>3-5</sup> Venoarterial extracorporeal membrane oxygenation (VA-ECMO)—also referred to as extracorporeal life support therapy—is being increasingly used to provide hemodynamic, oxygenation, and ventilation support to these patients. To be optimally effective, patients should be treated with CPR adjuncts that increase circulation when used in combination, including mechanical CPR with a LUCAS 3.1, an ITD-16, and the like.

### REFINING AN INNOVATIVE RESUSCITATION PROTOCOL

VA-ECMO works by removing blood from the patient's right atrium, superior vena cava, and inferior vena cava via a multistage cannula placed in the femoral vein. The pump moves the blood through an oxygenator which provides the blood with oxygen and removes carbon dioxide. The blood is then pumped back into the patient through an arterial cannula placed in the femoral artery. When deployed on scene of cardiac arrest, the technique is called extracorporeal cardiopulmonary resuscitation (ECPR). ECPR can be deployed quickly and safely in a variety of settings with highly trained staff and considerable resources.

Recent studies have shown a potential benefit of ECPR in select patients though randomized trials are not yet available.<sup>4,6</sup> Since 2016, the Minnesota Resuscitation Consortium (MRC) in Minneapolis and St. Paul has developed, refined and successfully implemented a protocol to coordinate the prehospital, emergency, and post-resuscitation care with respect to refractory ventricular fibrillation cardiac arrest.<sup>3</sup>

Patients between the ages of 18 and 75 who present to EMS with a shockable rhythm and are in ongoing cardiac arrest despite defibrillation and medical therapy, are included as candidates for



Anson Cheung, MD (left), emergency physicians, perfusionists, respiratory therapists, nurses, fellows and assistants take part in an ECPR simulation session in St. Paul's Teck Emergency Centre in Vancouver, Canada. Photo courtesy Brian Smith/St. Paul's Foundation



A team at the University of Utah puts a patient on extracorporeal cardiopulmonary resuscitation. Photo courtesy Scott Youngquist & Joseph Tonna

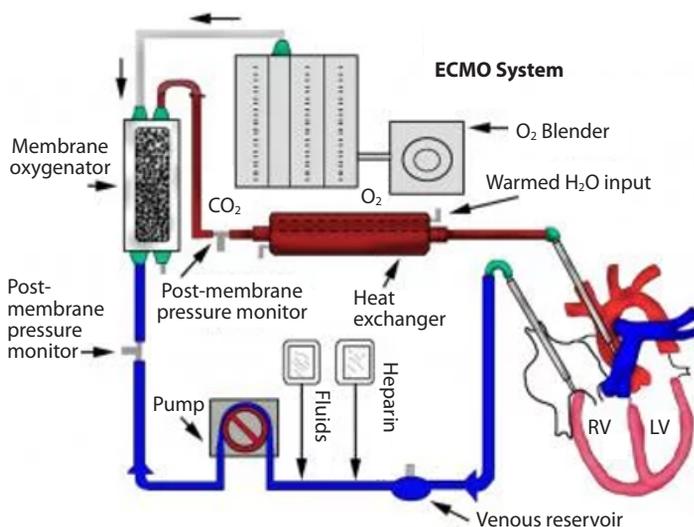
ECPR according to the protocol. These patients are emergently transported to the University of Minnesota where they're immediately taken to the cardiac catheterization laboratory (CCL) for ECPR, which is done within six to eight minutes of patient arrival. During this treatment the head is elevated to reduce intracranial pressures. Physiologic measures (end-tidal carbon dioxide, oxygen saturation and arterial lactic acid) are used on arrival to the CCL to determine if patients go on to receive VA-ECMO.

Using this protocol, the MRC has seen survival rates between 30% and 40%.<sup>7-9</sup> The success of the protocol and the positive response to VA-ECMO therapy means that the etiology of the arrest was likely severe and complex coronary artery disease.<sup>9</sup> It is therefore unlikely that return of spontaneous circulation (ROSC) would ever have been achieved until the underlying coronary artery disease was addressed.

The first consecutive 160 patients demonstrated a critical relationship between survival and time-to-initiation of ECMO.<sup>7</sup> That is, if patients were placed on VA-ECMO within 30 minutes of the initiation of CPR by EMS personnel, they had 100% survival.

However, this survival rate decreased by 25% with every subsequent 10 minutes of CPR.<sup>7</sup> This decline in survival was closely associated with the worsening metabolic derangement with prolonged CPR. Therefore, rapid transport and deployment of the VA-ECMO was critical.

**Figure 1: ECMO diagram**



## FUTURE DEVELOPMENTS

Rapidly identifying and transporting patients for timely ECPR provides substantial survival benefit in many patients suffering cardiac arrest. Although the MRC results clearly show that patients with refractory shockable rhythms receive a substantial benefit, it still remains unclear if patients with pulseless electrical activity (PEA) or asystole could also benefit. To fully understand the potential benefits and limitations for patients presenting with PEA and asystole will require further investigation.



**Ganesh Raveendran, MD, MS**, is the chief of clinical cardiology at University of Minnesota Health, the director of interventional cardiology and a professor of medicine at the University of Minnesota Medical School.

**Jason Bartos, MD, PhD**, is medical director of the cardiovascular ICU and assistant professor of medicine and the University of Minnesota.

**Demetris Yannopoulos, MD**, is the research director for interventional cardiology and a professor of medicine at the University of Minnesota Medical School. He's also the director of the Minnesota Resuscitation Consortium.

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# A MEDICAL FIRST

## Some called it a medical miracle

By David Hirschman, MD

& Charles Lick, MD

**D**uring our ICU rounds in mid-July 2019, we were discussing the case of Emmanuel, a 15-year-old boy who had drowned a week earlier, when several of our colleagues started talking about a miracle. “How could he have survived and woken up after drowning in a warm water pool? Nobody survives after 15 minutes underwater on a warm July day in Minnesota.”

After several minutes we chimed in: “Friends, this wasn’t a miracle, we used some new CPR devices together for the first time and they worked!”

### EMMANUEL’S STORY

Indeed, Emmanuel moved from Liberia to join his father for the dream of a new life in America in December 2018. He loved basketball and his new classmates, but, against his father’s request, went to play with his friends at their apartment in the same complex on July 11, 2019.

His father returned from work and learned a boy was drowning underwater in the apartment complex pool. The dad ran to the pool and jumped in but couldn’t get the boy up from the bottom on his first attempt.

When he resurfaced, he learned that it was his own son he was trying to save. His son had never learned to swim and accidentally fell into the pool. His dad’s second attempt to lift him up from the bottom of the 9-foot-deep pool was similarly futile.

Two New Brighton, Minn., police officers suddenly appeared on the scene, running down a hill to the pool carrying a host of cardiac arrest resuscitation equipment.

One officer ripped off his bulletproof vest, pulled his holstered weapon and handed it to his partner, and dove in. Within seconds, Emmanuel was removed from the pool and receiving manual BLS CPR with the combination of active compression-decompression (ACD) CPR and an impedance threshold device (ITD); components of ZOLL Medical’s ResQ CPR System carried by the patrol officers.

Emmanuel’s legs were still in the water and the

AED advised no shock. As CPR continued, the officers deployed the EleGARD head and torso elevation system that was recently added to the patrol officers’ vehicle. The device provides controlled, sequential elevation of the head and thorax.

After 15 minutes, a LUCAS mechanical chest compression device was used in place of the manual ACD CPR pump to ensure consistent compressions and free up the officers, and other rescuers to attend to Emmanuel.

After 20 minutes of poolside mechanical CPR, a pulse returned. Five minutes later, Emmanuel was breathing on his own. And while en route to Children’s Hospital of Minneapolis, he started pulling on his ET tube.

Then the debate began, to cool or not to cool? There is no definitive data in this area, so discussion ensued. After a lengthy back and forth, we agreed that he should be cooled, so then we discussed whether to cool him to 33 degrees C, or cool him to just 36 degrees C. We agreed to take



Emmanuel with staff on the day of his discharge from the rehab facility.

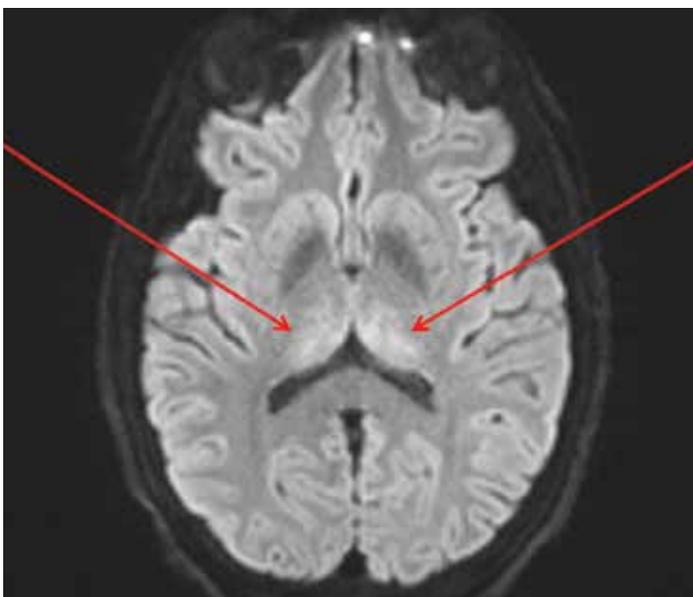


**New Brighton, Minn., police officers who rescued and resuscitated Emmanuel.**

him to 36 degrees C.

Putting together the reports from witnesses and the 9-1-1 response times, Emmanuel was estimated to have been submerged under water for at least 13–17 minutes. So, then we waited for the dreaded brain edema that occurs ever so commonly, if not inevitably, after a prolonged warm water drowning.

Between 4–48 hours after his arrest, Emmanuel’s EEG summary read, “The background is diffusely slow and nonreactive. It becomes more suppressed toward the part of the recording. The



**Figure 1: MRI T2 signal abnormality and restricted diffusion involving the bilateral thalami concerning for ischemic change.**

findings suggest a non-specific encephalopathy. No seizures are noted.”

His head MRI was worrisome, with diffuse mid-brain swelling bilaterally. (See Figure 1.)

Then, on day five, he started moving his arms and legs and, by day seven, he was trying to wake up.

Three weeks after his cardiac arrest Emmanuel walked, normally, out of Children’s Hospital to Bethesda, our local rehab hospital.

Less than three weeks later he left Bethesda and returned to high school in the fall.

## DISCUSSION

We caught up with Emmanuel and his family at an awards ceremony for the New Brighton police heroes who saved him, and then later at his apartment where we discussed his remarkable recovery.

Although Emmanuel and his father report that he had to learn how to talk, eat, move, walk and throw a baseball, all over again, as though he never knew how to perform any of these tasks, his cognitive ability post-resuscitation was amazing. A resuscitation specialist who visited him brought him a chess set for Christmas, and, incredibly, within minutes, Emmanuel learned the names of each of the game pieces and the appropriate moves for each! He was waiting eagerly for clearance to play basketball again.

So, was this a miracle resuscitation? It may not be miraculous, but it’s certainly a remarkable resuscitation that occurred following the first police deployment of the combination of ACD+ITD CPR and head up CPR with the EleGARD device.

The New Brighton Police Officers are first responders who take their jobs seriously, members of a police department that’s actively involved in EMS training and resuscitation science, and that’s interested in adopting and utilizing the latest resuscitation tools.

We have known about head up CPR since 2015 and were the first to have a save with it when it was introduced into the Anoka County Minnesota EMS system in April 2019.

We believe that the New Brighton Police may have been the only police in the world to carry and utilize all three devices (ResQPUMP, ITD, EleGARD) at all cardiac arrest cases, such as at the time of Emmanuel’s resuscitation.

We know from multiple studies that ACD+ITD CPR generates a significant intrathoracic vacuum during the decompression phase of CPR and results in a doubling of blood flow to the heart and brain and 50% more 1-year survivors after out-of-hospital cardiac arrest in adults.

We also now know that controlled sequential elevation of the head and thorax during CPR with

ACD+ITD doubles brain blood yet again, lowers intra-cranial pressure (ICP) immediately, and nearly normalizes cerebral perfusion pressures.

Finally, we also now know that conventional manual CPR in the flat position, which nearly everyone still receives, not only just propels 25% of normal blood flow forward, but also propels venous blood backwards, and causes the ICP to increase with each compression. This effectively creates a brain concussion with each compression, as the high-pressure arterial and venous pressure compression waves reach the brain simultaneously.

It has been shown that ACD+ITD CPR, along with controlled elevation of the head and thorax, mitigates against this harmful combination of ischemia, anoxia, and high ICP from the CPR.

In Emmanuel's case, his head was always elevated higher than the rest of his body, with CPR initially performed with his feet in the water while his torso and head were on the side of the pool. Next his head and heart were elevated by the police officers via the EleGARD.

The whole time he received ACD+ITD CPR and then mechanical CPR via the LUCAS compression device. This combination has been shown in the pig lab to result in sustained and normal cerebral perfusion pressures, and a six-fold higher neurologically intact survival rate compared with conventional flat CPR.

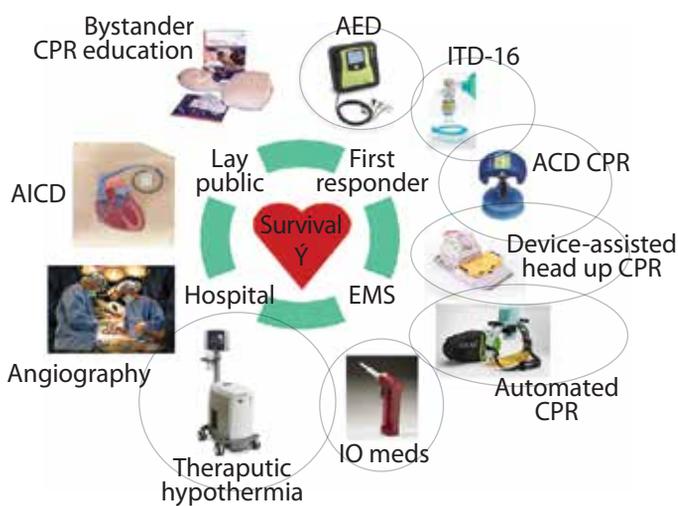
## CONCLUSION

Emmanuel was successfully resuscitated as a result of fast, state of the art knowledge and technology by the police officers of the New Brighton police department. (See Figure 2 for the bundle of care used by the progressive law enforcement agency.)

It takes the whole bundle, including controlled patient hypothermia, to help save a young child such as Emmanuel. Hypothermia shouldn't be controversial in a 15-year-old teenager: a reduction in core temperatures to 33 degrees C for 24 hours works in adults 18 years of age and older, so we believe it is only common sense that it be utilized in selected patients under the age of 18.

Emmanuel survived after a terribly unlucky fall into a swimming pool, despite having never learned to swim in his native Liberia. He is back playing basketball, his favorite sport, and is thriving in school.

The New Brighton City Council offered him and his friends free swimming lessons at the award ceremony for his rescuers. We know swimming is a life skill all should learn. We offer you another life skill, a way to increase the likelihood for full restoration of life after cardiac arrest, for anyone who needs it. This new approach focuses on technologies



**Figure 2:** The Take Heart America bundle of care techniques and technologies used to resuscitate Emmanuel.

that when used collectively restore normal brain flow and lower ICP and prevent reperfusion injury. Emmanuel's remarkable case should become the blueprint for all patients in need of CPR.

We need our police officers, medics, nurses, and doctors to understand these breakthroughs and to use them as the new standard of care. It would be an enormous step forward and a gift for all future patients who would benefit from this first very unlucky and then very lucky boy from Liberia.

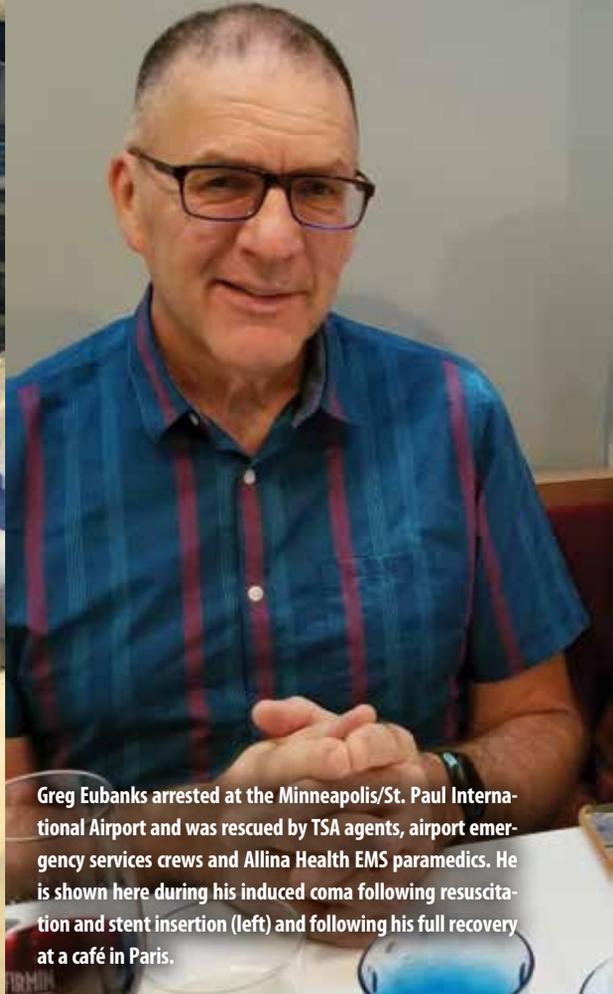


**David Hirschman, MD**, is medical director of emergency services at Children's Hospital in Minneapolis, Minnesota.

**Charles Lick, MD**, is medical director for Allina Health EMS in Minnesota.



An alert and exuberant Emmanuel at home with his parents at Christmas 2019.



Greg Eubanks arrested at the Minneapolis/St. Paul International Airport and was rescued by TSA agents, airport emergency services crews and Allina Health EMS paramedics. He is shown here during his induced coma following resuscitation and stent insertion (left) and following his full recovery at a café in Paris.

# MIRACLE IN MINNEAPOLIS

## How orchestrated use of the Bundle of Care saved Greg Eubanks

By A.J. Heightman, MPA, EMT-P

**W**hen 60-year-old Greg Eubanks exited his plane at the Minneapolis/Saint Paul (MSP) airport on Aug. 10, 2019, to catch a connecting flight to San Diego after visiting his mother in Indianapolis, he had no idea that a widow-maker blockage and clot was about to occur and send him into sudden cardiac arrest.

He was also unaware that he was walking through one of the world's best prepared airports

for cardiac arrest, and that MSP crews would respond and resuscitate him with highly choreographed care, coordinated with the precision of an Apollo moon landing.

Also unknown to Greg, or the traveling public in general, was the fact that, in addition to the having AEDs strategically positioned throughout the airport, MSP airport's police officers, TSA agents, firefighters, as well as Allina Health EMS paramedics, had worked diligently for years to fine tune their EMS response and cardiac arrest approach to employ all of the bundles of care recommended by the nonprofit Take Heart America resuscitation coalition, which is based in Minneapolis.

In fact, the MSP Airport EMS system has been so successful in their goal of resuscitating cardiac arrest victims that the airport has achieved an amazing 35% ROSC survival rate.

**Table 1: Airport video timeline of Charles Eubanks rescue**

<b>Airport Camera Elapsed Time (mins:secs)</b>	<b>Action and/or Care</b>
00:00	Greg collapses in cardiac arrest.
00:05	Bystanders alert nearby TSA Agents.
00:09	TSA Agents rush to Eubanks' aid in nine seconds.
01:50	Assessment and start of CPR by TSA Agent Eric Jones within 30-60 seconds.
04:22	TSA Agent Jones and airport police officer deliver first shock.
05:34	Airport fire crews utilize ResQPUMP and ITD to enhance compressions.
06:20	Minneapolis/St. Paul Airport Fire Department EMTs insert an i-gel rescue airway, ResQPOD and BVM with O <sub>2</sub> .
	Second AED shock delivered without return of spontaneous circulation (ROSC).
09:24	EleGARD Patient Positioning System placed into operation to assist in elevating Greg's head and the thorax to support the practice of head-up CPR to reduce intracranial pressure and improve cardiac perfusion of his brain.
13:51	Allina Health EMS ALS crew Stephanie Lee, EMT-P, and Jessica Cross, EMT-P, arrive on scene. They are advised that the patient has already been defibrillated five times with the AED without success.
14:48	Intraosseous (IO) lifeline place by Lee and Cross for medication administration.
15:14	Epinephrine and amiodarone administered by Lee and Cross.
17:08	LUCAS II mechanical chest compression system put into operation.
20:50	Defibrillation and first ROSC achieved.
22:45	Greg re-arrests so mechanical CPR restarted, and Greg defibrillated seven more times.
22:57	Additional epinephrine and amiodarone administered as CPR continues.
26:33	Patient packaged for transport with LUCAS II CPR continued.
30:15	Greg is defibrillated for the eighth time and ROSC is regained and not lost throughout transport. Because he was agitated, uncomfortable and grunting, Versed was administered and he was less agitated upon arrival at the receiving hospital.

On this day, Greg was about to contribute to this stellar track record, in addition to being the first airport code resuscitated with the revolutionary new EleGARD Patient Positioning System, a device that allows for delivery of head-up CPR.

### THE MOMENT OF IMPACT

It is unusual to be able to determine exactly when a widow-maker occlusion strikes a victim, or when they collapse. But, in Greg's case, his temporary death, and the extraordinary care he received, was all captured on airport security cameras. (Watch the video at <http://tiny.cc/MplsAirportSave>.)

As Greg moved briskly in his usual stride to board his next flight, but with a bit of a limp prior to his planned knee replacement, he's shown collapsing, knees first, to the floor in Concourse G, within eyesight of a TSA checkpoint. He had no warning, experiencing no chest pain or anything.

Perhaps because Greg exhibited classic gasping, agonal respirations and seizure activity that frequently occurs in the first moments of many cardiac arrests, none of the bystanders initially

rolled him over nor began chest compressions for almost two minutes.

However, the first essential element in the bundle of care, recognition, dispatch and citizen response, were fulfilled rapidly as several people rushed to alert the nearby TSA agents, and others called 9-1-1 to report his collapse.

Two TSA Agents, Eric Jones and Brittany Sutton, rushed to Greg's aid and were at his side in 9 seconds after being notified by the bystanders. (See Table 1 for a timeline as captured on video.)

Agents Jones and Sutton were also puzzled by his gasping but then quickly rolled Greg over and, after a rapid pulse check, Jones immediately began compressions and Sutton ran to retrieve the nearest AED.

As Jones administered chest compressions, Greg gasped but didn't regain consciousness.

Airport police and fire personnel arrived almost simultaneously with the AED and assisted in its application. Jones, Sutton and the MSP airport fire team inserted an i-gel airway, applied the AED pads and delivered the first debrillator shock.

There was no conversion. The BLS airport fire crew arrived and started using the ResQPUMP for ACD CPR and the ResQPOD ITD. They shocked Greg eight times but weren't able to get his heart to convert out of v fib with the airport AED.

After about nine minutes, the fire crew applied the EleGARD—the first time a heads-up CPR positioning device was put into operation in any U.S. airport—and slowly elevated Greg's head, by protocol, to reduce intracranial pressure and increase cardiac perfusion to his brain. (See Figure 1.)

The Allina Health EMS ALS ambulance crew was originally dispatched to a report of an “unconscious/fainting” male, a common misreport to 9-1-1 by the general public, confused by the patient's agonal breathing and seizures as a fainting episode. Recognition of agonal respirations and seizure activity is an educational task that most EMS systems are now working on in addition to public awareness of recognizing and responding to a witnessed sudden cardiac arrest (i.e., start CPR, call 9-1-1, get an AED).

The call to the Allina Health EMS ALS crew was upgraded to a cardiac arrest as soon as the airport police and fire responders arrived on scene.

When Allina paramedics Jessica Cross and Stephanie Lee arrived, they found Greg unconscious with clammy, warm, slightly pale skin. Good



**Greg Eubanks with TSA Agents Brittany Suttan (left) and Eric Jones (right).**

**Figure 1: EleGARD Patient Positioning System**



**The resuscitation of Greg Eubanks at the MSP Airport marked the first use of the EleGARD patient positioning system, a head-up CPR positioning device, in an airport in the United States.**

CPR was underway with the ResQPUMP and ITD combination. Cross and Lee were advised that the patient had already been defibrillated more than five times without conversion.

The paramedics applied the LUCAS 2 mechanical chest compression device, freeing them up to focus on the delivery of ALS interventions for Greg.

Using a practiced pit crew approach, the paramedics positioned themselves to care for Greg in an integrated manner with the MSP Airport Fire Department first responders. As an IO was initiated by one paramedic for medication delivery, the second paramedic placed Greg on their cardiac monitor and found him to be in v tach. He was defibrillated and ROSC was finally obtained—nearly 21 minutes after he collapsed from v fib.

Greg went into cardiac arrest again two minutes later and resuscitation was continued. CPR was restarted and he was given two doses of epinephrine (1 mg) and a dose of amiodarone (300 mg). ROSC was again obtained nine minutes later, after seven additional shocks.

After being in refractory v fib for quite some time, an additional 150 mg of amiodarone was administered prior to ROSC being regained and sustained after 10 shocks in total. He stayed in normal sinus rhythm and the paramedics began preparing him for transport.

It's important to note that, as often is the case, AED defibrillation shocks alone are not the sole savior that converts a patient back to a normal heart rhythm. An AED doesn't work in more

**Table 2: Record of actions taken by Alina Health EMS paramedics while on scene**

Time of Day	Allina Health EMS ALS Crew Elapsed Time (mins)	Action	Pulse rate (per min.)	Resp. Rate (per min.)	Blood Pressure (mmHg)	SpO <sub>2</sub>	EtCO <sub>2</sub>	Notes
8:24 PM	0	Defib #1	0					First defibrillation by Allina Health EMS
8:24 PM	0	ResQPUMP	72			88		FD CPR via ResQPUMP Compression Device
8:26 PM	2	LUCAS 2	M138			71		Compressions discontinued; ROSC obtained
8:27 PM	3	Defib #2	ROSC					2nd defibrillation and ROSC by Allina Health EMS
8:29 PM	5	Pt. Vitals	62	20		65	27	
8:31 PM	7	Pt. Vitals	100	21		90	32	
8:32 PM	8	Defib #3	122			66		
8:36 PM	12	Pt. Vitals	111	21		77	33	
8:36 PM	12	Pt. Vitals	114	22	191/105	81	34	
8:39 PM	15	Pt. Vitals	114	22	177/100	71	35	
8:41 PM	17	Pt. Vitals	120	22		83	34	
8:43 PM	19	Pt. Vitals	117	21	187/131	73	37	
8:44 PM	20	Pt. Vitals	115	19	133/84	80	37	
8:46 PM	22	Pt. Vitals	111	23		80	30	
8:50 PM	26	Pt. Vitals	110	24	115/54	90	30	

**Aid initially rendered by MSP Airport Fire first responders prior to arrival of Allina Health EMS paramedic crew: AED with no conversion; bagged (for BVM ventilations) with a supraglottic i-gel airway inserted; ResQPOD ITD attached to airway; ResQPUMP active compression-decompression CPR device used during CPR; EleGARD patient positioning system applied and in use for head-up CPR; oxygen by positive pressure device.**

than 50% of patients who have v fib. More circulation is often needed to convert the patient successfully. The ITD and EleGARD both help to increase brain and heart circulation, as well as reduce intracranial pressure to avoid an internal concussion with each compression.

It is the complete bundle of care package that prepares the patient for successful conversion and resuscitation with full neurological recovery. This includes early and consistently delivered cardiac compressions, use of an ITD, elevation of the patient’s head and torso, mechanical or otherwise assisted chest compressions, medications, and defibrillations are all keys to resuscitation success.

Greg appeared agitated and uncomfortable after ROSC, moving his head back and forth in the EleGARD cradle and grunting, so paramedics administered 5 mg of Versed IO to help reduce his agitation. During transport, his respiratory rate was maintained in the upper 20s, so fire personnel just assisted his respirations.

He was transported to the hospital where he was found to have a widow-maker blockage, a 100% occlusion of the left anterior descending coronary artery, which was opened, and a stent applied. Greg was kept in an induced coma, received hypothermia therapy (at 33 degrees C) and gradually improved.

### AN UNUSUAL NOTIFICATION

Meanwhile, Greg’s wife, Laura, was waiting in the San Diego airport cellphone lot on Aug. 10, wondering why her husband hadn’t yet called her to pick him up at the terminal. She texted him and, very soon thereafter, received a call from his phone. She quickly answered, but it wasn’t her husband on the line. It was his Minneapolis cardiologist relaying news that no wife wants to hear: Her 60-year-old husband had suffered a cardiac arrest at the Minneapolis-Saint Paul (MSP) airport.

Laura was stunned, later stating, “He had no symptoms—no dizziness, no shortness of breath. He felt fine. And then he was dead. It happened that fast.”



Greg's son Jon grasps his father's hand as he is awaking from his induced coma.



Laura Eubanks, Greg's wife, kisses her husband after he awakens from his induced coma.



Greg celebrates his "rebirth" with his family at Abbott Northwestern Hospital. (From left, back row: Hannah, Liz, Alex, Jon and Mary Ann Eubanks, MD. Front row Greg and Laura Eubanks.)

As doctors finished opening Greg's blockage and putting him into a medically induced coma, Laura and the couple's four adult children scrambled to book flights to Minneapolis.

Greg emerged from his coma just after rewarming and recognized a family member at his bedside. Everyone was amazed he could both walk and speak following his ordeal. He was released from the hospital—neurologically intact—after only five days.

Greg and his family were anxious to thank his rescuers and give them the good news. So, they followed appropriate channels to learn the names of the TSA agents. They were able to locate Sutton and Jones, and the next day both agents came to the hospital.

"It provided such closure for Greg to be able to hear what had happened, and for the TSA agents to see that he had made it," Greg's wife, Laura said. "It was a very, very emotional reunion—extremely powerful."

Greg describes meeting his rescuers as, "the best therapy I could ever have. All I remembered was the plane landing and walking up the ramp to go to the gate in the terminal to catch my next flight. They were able to fill in the blanks for me. They

are part of my extended family now."

Greg was cleared to return home to San Diego. Jones and Sutton weren't on security duty when Greg and his family were set to depart, but they arrived at the MSP airport in uniform and personally escorted the Eubanks family through TSA to their departure gate. Greg admitted that returning to the airport where he had collapsed was a traumatic experience for him.

### 'I SHOULDN'T BE HERE'

On Aug. 10, 2020, a year after his resuscitation, Greg Eubanks posted a heartwarming video on YouTube expressing his feeling about how the EMS system and precision of the Bundle of Care allowed him to survive. Watch the video at <https://youtu.be/gDq0vUr67HM>.



**A.J. Heightman, MPA, EMT-P**, is Editor Emeritus of the *Journal of Emergency Medical Services (JEMS)* and chairman of EMS Today: The JEMS Conference and Exposition. He served as Editor-in-Chief of *JEMS* for 26 years and is a member of the Industry and Scientific Advisory Committee of Take Heart America. He can be contacted via email at [aj.heightman@clarionevents.com](mailto:aj.heightman@clarionevents.com).



A.J. Heightman with Greg and Laura Eubanks at their home in Chula Vista, Calif.

### SO MUCH MORE TO THE STORY

When I read the *San Diego Union-Tribune* on Saturday, August 24, 2019, a small article on the resuscitation of a San Diego County resident caught my attention because it credited the quick action by two TSA agents at the Minneapolis/Saint Paul Airport in reaching the victim (Greg Eubanks), starting CPR and retrieving a nearby AED.<sup>1</sup>

But, as I read on, I realized that much of the story was not being told. I said to my wife, “Hey, this article is omitting so much of why they were



Hanna, Laura, Greg and Alex Eubanks at their home in Chula Vista, near San Diego.



A.J. Heightman and Laura Eubanks exchange succulent plants—their joint passion—as a show of their new friendship.

able to save sudden cardiac arrest victim. I know that prehospital and airport EMS System well and they practice all of what I and the other members of the Take Heart America members espouse about coordinated and necessary resuscitation practices. They do every one of the ‘Bundle of Care’ procedures, including the Minneapolis/St. Paul Airport fire department’s use of the ResQCPR system and the EleGARD, a head-up CPR patient positioning device.”

I picked up the telephone and called the Eubanks residence, asking Greg’s wife if she and Greg knew about the “Bundle of Care” that resulted in his successful resuscitation and briefly explained it to her. She was amazed about how much of the resuscitation story they did not know. I then asked if she and Greg would consent to a video interview with me to discuss his amazing recover and the Bundle of Care. She graciously consented and I met with them in their Chula Vista, CA home on August 28, just 18 days after his cardiac arrest.

The video of my amazing discussion with the Eubanks family can be viewed at <https://youtu.be/CuCRYJv5nvQ>.

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From left: A.J. Heightman, Laura Eubanks, Dr. Charles Lick, Greg Eubanks and Dr. Keith Lurie at the Paris Conference surprise appearance.

### A BIG SURPRISE IN PARIS

Greg Eubanks told Dr. Keith Lurie, co-founder of Take Heart America, and me that he wanted to someday personally thank Allina Health EMS Medical Director Charles Lick for his role in the development and use of the complete, coordinated Bundle of Care approach to resuscitation that saved his life.

The entire Take Heart America organization was also impressed not only with the resuscitation of Greg Eubanks and his amazing recovery, but also his zealot-like advocacy of the Bundle of Care approach.

So, Dr. Lurie decided to secretly organize a trip to Paris, France, for Greg and his wife Laura to surprise Dr. Lick, the faculty and the attendees at the State of the Future of Resuscitation Conference.

My wife Betsy and I were assigned to keep Greg and Laura out of sight until the last session of the conference. We dined out and went to the Eiffel Tower at night, a great sight to celebrate Greg’s new life.

We pulled it off without a hitch and Greg was a hit at the conference. It was a memorable moment and a wonderful surprise for Dr. Charles Lick.



Greg and Laura Eubanks at the Eiffel Tower.

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1. Schepke, et al., Prehospital Emergency Care, 2020



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