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RESUSCITATION SUCCESS

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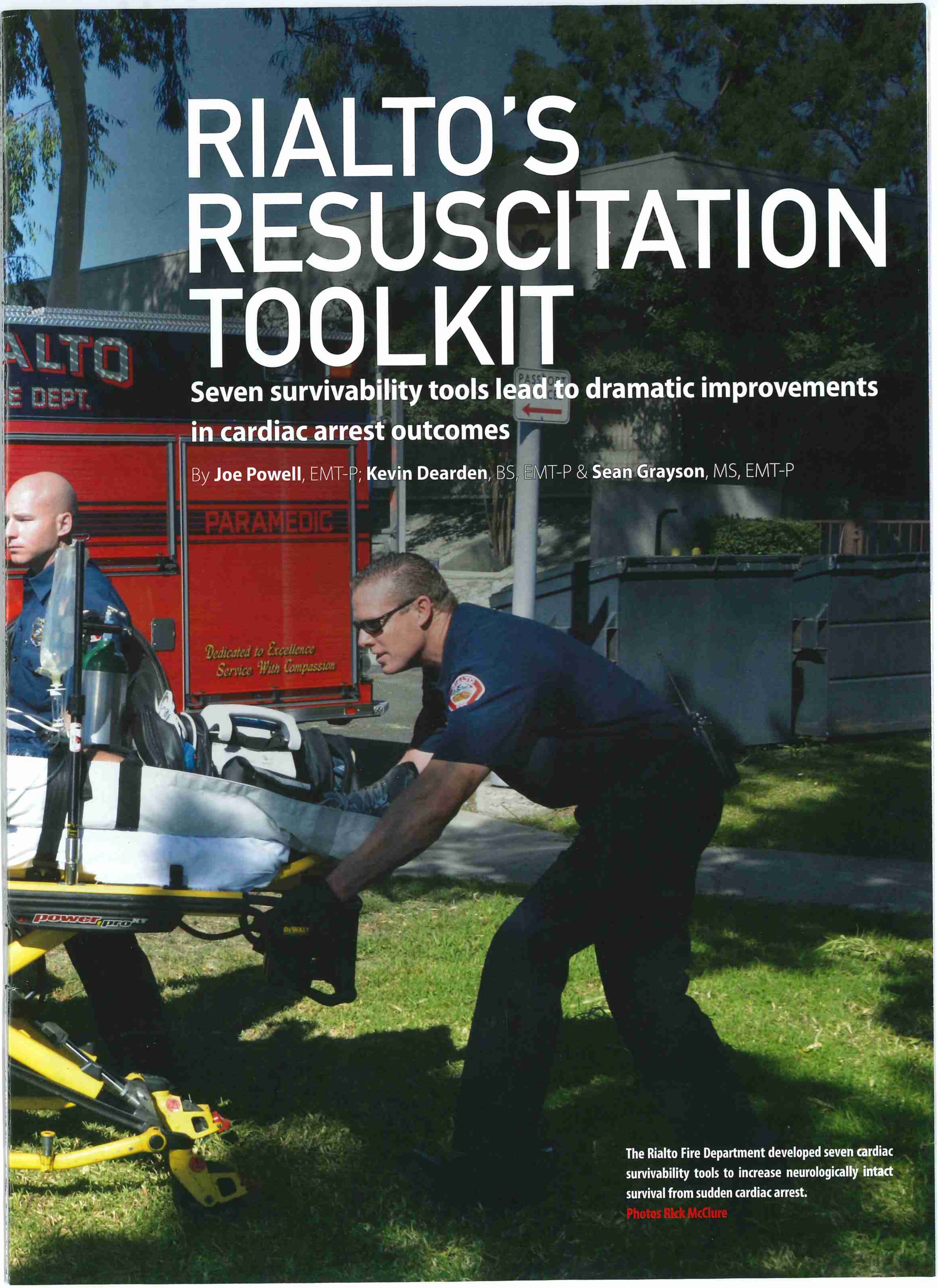
RIALTO'S RESUSCITATION TOOLKIT

Seven survivability tools lead to dramatic improvements in cardiac arrest outcomes

By **Joe Powell**, EMT-P; **Kevin Dearden**, BS, EMT-P & **Sean Grayson**, MS, EMT-P



The Rialto Fire Department developed seven cardiac survivability tools to increase neurologically intact survival from sudden cardiac arrest.
Photos Rick McClure

Apneic oxygenation allows for passive oxygenation of a patient who's already receiving continuous, uninterrupted compressions.

In the United States, an estimated 10% of cardiac arrest patients survive, with 90% never leaving the hospital.[1] Are these acceptable cardiac arrest survival rates where you and your family live, work and play? They weren't for the Rialto (Calif.) Fire Department (RFD), so the RFD embarked on a complete review and revision of their approach to cardiac arrest resuscitation.

This article describes the RFD's journey toward increased SCA survival—a journey that, in 2016, resulted in a 71% (Utstein) survival rate from sudden cardiac arrest (SCA) in Rialto. This is due in large part to what the RFD *unlearned* about cardiac arrest; Rialto's outcome-based data now shows that all of these assumptions are *false*:

- CPR should be done on a hard, flat surface;
- Always defibrillate ventricular fibrillation (v fib);
- Intubation attempts should be limited to 30 seconds;
- ALS actions are what saves lives;
- Prioritize epinephrine to improve cerebral perfusion and survival;
- Asystolic patients have essentially no survivability; and
- Rapid transport to the hospital improves outcomes.

After just two years, the RFD is seeing dramatic results, including a significant improvement of ROSC and patient survival.

The RFD's mission is to be, "An organization that brings value to the community, measured in lives saved and quality of life protected."[2] To further this, the RFD embarked on a journey to improve neurologically intact survival from SCA.

The RFD enjoys an organizational structure that isn't common in California. The RFD is both the fire-based first responder and the ambulance transport provider for the city of Rialto.

All RFD first responder and transport units are staffed with paramedics and all RFD personnel are trained to the same standards. The RFD doesn't participate in the CARES registry and acquiring outcome data depends upon extending the RFD culture of teamwork to receiving facilities.

RIALTO'S TOOLKIT

In 2016, the RFD developed the seven components of cardiac survivability, referred to as the RFD Cardiac Survivability Tools:

1. Continuous uninterrupted compressions utilizing an automated CPR device;
2. Apneic oxygenation;
3. Use of an impedance threshold device (ITD);
4. Heads-up CPR;
5. Delaying defibrillation for a certain subset of patient presentations;
6. Expanded utilization of waveform capnography; and
7. Deprioritizing epinephrine in the order of interventions.

When applying the RFD Cardiac Survivability Tools to cardiac arrest patients, the RFD realized a 60% return of spontaneous circulation (ROSC) for all non-traumatic adult arrests; not just the very small number of patients that fit into the Utstein measurement, but *all* patients in cardiac arrest. By working hard at this process and unlearning previous assumptions, the RFD gleaned some keys to success.

UNINTERRUPTED COMPRESSIONS

If the RFD could impart only one data-driven, outcome-oriented finding, it's this: nothing trumps compressions, *nothing*! Not ALS or BLS, airway or venous access, defibrillation or definitive medical care; nothing should interrupt compressions. Uninterrupted compressions have been shown to be one of the key components to saving lives, so everything else should be support for those compressions.

The RFD has been using the AutoPulse automated CPR device since 2009. The generalized research on automated CPR devices hasn't shown significant benefit in patient outcomes with their use.[3] Research conducted in 2015 illustrated ROSC rates to be 5% higher for all non-traumatic adult cardiac arrest patients in Rialto with use of automated CPR vs. manual CPR

However, it was when evaluating the use of automated CPR devices that the RFD had its first eureka moment—a moment that would set the stage for the data-driven, outcome-oriented cardiac survivability tools that would follow.

The RFD was using automated CPR in the same fashion it had previously used manual CPR—with too many pauses in compressions. Today, the RFD goal is to initiate and maintain continuous, uninterrupted compressions as soon as possible after patient contact, effectively maintaining a 100% compression fraction rate within the first 30 seconds of the resuscitation.

In practice, RFD crews will initiate manual CPR, transition to the AutoPulse device within 30 seconds and then *never* turn off the device; not for intubation, defibrillation, rhythm checks or pulse checks.

Under RFD's cardiac arrest protocol, the automated CPR device can only be turned off for two reasons: termination of resuscitation efforts or if ROSC is achieved, as noted by a precipitous and persistent increase in end-tidal carbon dioxide ($EtCO_2$).

To ensure compliance with the Cardiac Survivability Tools, the RFD uses software (ImageTrend ePCR report writer and ZOLL Case Review) to review all sudden cardiac arrests. Each compression, ventilation and all vitals are represented for the duration of the resuscitation in the program.

Those patients that achieve ROSC share an extended period of uninterrupted high-quality CPR as the underlying factor. Although patients in shockable rhythms generally achieve ROSC as a result of defibrillation, those who achieve ROSC from non-shockable rhythms generally have no discernable causal intervention other than the absence of breaks in CPR for several minutes prior to ROSC.

APNEIC OXYGENATION

For years, paramedics have been taught that 30 seconds is all the time they have to establish an advanced airway, or the intervention should be delayed and a round of pre-oxygenation ventilations should be instituted. Apneic oxygenation allows for passive oxygenation of a patient that's already receiving continuous, uninterrupted compressions, capitalizing on the low tidal volume but high minute volume of ventilations generated by the automated CPR device.[4]

Patients that achieve return of spontaneous circulation share an extended period of uninterrupted high-quality CPR as the underlying factor.

The RFD goal for this survivability tool is to initiate and maintain continuous oxygenation of patients from the time that continuous, uninterrupted CPR by automated CPR device is initiated until an advanced airway is secured.

In practice, crews place a nasal cannula on the patient at 15 liters per minute immediately after initiating the automated CPR device.

Providers can readily assess the effectiveness of apneic oxygenation through the use of pulse oximetry. The patient should maintain or improve their oxygen saturation and $EtCO_2$ levels even when providers aren't ventilating the patient to secure an advanced airway.

Applying this tool supports the entire process by avoiding interruption of CPR to secure an advanced airway and eliminates arbitrary time standards to secure the advanced airway based on the need to maintain patient oxygenation.

REGULATING INTRATHORACIC PRESSURE

The RFD uses the ResQPOD ITD, a non-invasive device that delivers intrathoracic pressure regulation (IPR). The ITD acts as a one-way valve allowing oxygen to be delivered during ventilations but restricts ambient air from entering the thoracic cavity during the recoil phase of chest compressions and between ventilations. This lowers thoracic pressure, creating a vacuum which pulls more blood back to the heart, increases preload and decreases intracranial pressure (ICP), allowing for quality cerebral perfusion. It's a blood in, blood out equation. Studies have shown that the ITD increases blood flow to the heart by 25% and increases cerebral perfusion by 50%.[5–7]

The RFD goal for this survivability tool is to increase cardiac and cerebral perfusion by initiating and maintaining the use of the ITD from the time an advanced airway is secured until ROSC is achieved. In practice, crews place the ITD inline of the ventilation circuit immediately after verifying placement and security of the advanced airway.

The RFD hasn't found a definitive indicator that the ITD is providing increased circulation. However, for patients who subsequently achieve ROSC, there's generally noted improvement in $EtCO_2$ from the time of ITD placement. This improvement in $EtCO_2$ occasionally occurs rapidly and, in several cases, has precipitated ROSC without additional intervention.

HEADS-UP CPR

Performing heads-up CPR, with the patient's head and torso in a 30-degree elevated position, has been found to optimize perfusion in the shock state of cardiac arrest. It's a simple, yet effective way of decreasing ICP, increasing preload and enhancing post ROSC neurological function.[8]

By elevating the head to a 30-degree angle, venous pressure is relieved and allows gravity to drain blood back to the heart. Decreasing ICP and increasing preload allows for more blood in and more blood out of the brain. From an ergonomic and effectiveness perspective, heads-up CPR can only be performed with an automated CPR device and should only be performed with an ITD in place to maximize the pressure variant and cerebral perfusion. Heads-up CPR has a synergistic effect when provided as a concomitant therapy to the ITD.[9]

For heads-up CPR, the most recently implemented cardiac survivability tool, the goal is to initiate and maintain heads-up CPR from the time the ITD is placed until ROSC is achieved. In practice, once the automated CPR device is in place, crews move the patient onto the stretcher and then raise the head of the gurney to a 30-degree angle.

Rialto Fire Department's goal for automated CPR delivery is to initiate and maintain continuous, uninterrupted compressions as soon as possible after patient contact.

Once the automated CPR device is in place, crews quickly move the patient to the gurney and then raise the head/shoulders to a 30-degree angle.

Although the RFD hasn't found a definitive indicator that heads-up CPR is providing increased circulation, the same improvement in $EtCO_2$ has been seen in those patients who subsequently achieve ROSC when heads-up CPR is initiated immediately after the placement of the ITD.

After heads-up CPR was added as a survivability tool, RFD crews found that many patients who eventually achieved ROSC were noted to gasp or provide patient-initiated ventilation attempts within a short period of time after heads-up CPR was initiated. The gasping response hasn't been historically documented and is an anecdotal corollary finding. It may not be caused by heads-up CPR; however, during heads-up CPR, gasps have been observed along with a discernable capnography waveform.

DELAYED DEFIBRILLATION

One of the links in the chain of survival is early defibrillation. Matching national data, 24% of RFD patients have an initial presenting rhythm of v tach or v fib, the two classic shockable rhythms of cardiac arrest.

The RFD provides early defibrillation to patients in shockable rhythms whenever possible. Unfortunately, the arrival of responders may occur after the window in which defibrillation will result in ROSC has closed.

There are three clinical findings that suggest the patient is outside the window for early defibrillation such that defibrillation may not be successful: 1) prolonged patient downtime in cardiac arrest; 2) very fine v fib (barely distinguishable from asystole);[10] and 3) an $EtCO_2$ reading of less than 20 mmHg.[11] Patients with these clinical findings are acidotic and have hearts that are less receptive to electrical therapy. Before defibrillation, these patients require high-quality CPR to increase perfusion, correct hypoxia and resolve the acidosis.

For patients who meet one or more of the three clinical findings for deferred defibrillation, the RFD goal for this survivability tool is to implement the four previous tools (continuous, uninterrupted compressions utilizing an automated CPR device; apneic oxygenation; use of an ITD and heads-up CPR) for a minimum of five minutes prior to delivering defibrillation.

Case review and field providers have been able to assess the effectiveness of this practice by a decrease in the number of defibrillated patients that convert into asystole and an increase in the number of defibrillated patients that ultimately achieve ROSC.

EXPANDED USE OF CAPNOGRAPHY

$EtCO_2$ levels provide information that cells are alive and metabolically active. Waveform capnography can help verify the continued placement of an advanced airway, and it can help guide delayed defibrillation.

Waveform capnography can also be an indicator of a patient who may ultimately survive but may require additional time for resuscitation. The common practice of terminating resuscitation for an asystolic patient after two rounds of medications or 10–15 total minutes may be limiting survivability. The RFD uses $EtCO_2$ to help guide this decision.

The goal for this valuable tool, which is integrated into the X Series monitor/defbrillator used by the RFD, is to ensure that patients who show signs that resuscitation may result in ROSC continue to receive care unless clinical findings determine otherwise.

In practice, the RFD only terminates resuscitation efforts if the $EtCO_2$ is less than 15 mmHg and trending downward (after confirming that high-quality resuscitation is being performed with all of the previously noted cardiac survivability tools).

If a patient has an $EtCO_2$ that's greater than or equal to 15 mmHg and is trending upward, RFD crews remain on scene, providing all of the survivability tools for at least 30 minutes before transporting or terminating resuscitation.

Even providers who were initially highly skeptical of this requirement have seen positive results. The RFD rate of ROSC for the initial presenting rhythm of asystole, including unwitnessed arrests, is 26%. Of those patients, the average time from arrival of RFD crews until ROSC is 24 minutes. All of those patients had an initial $EtCO_2$ greater than or equal to 15 mmHg. Half of those patients survived to hospital discharge.

> *The common practice of terminating resuscitation for an asystolic patient after two rounds of medications or 10–15 total minutes may be limiting survivability.*

DE-EMPHASIZING EPINEPHRINE

The type, dosage and priority of administration of medications in cardiac arrest has varied dramatically over time. Matching national standards, local EMS protocols that the RFD operates under require epinephrine administration as the first pharmacological intervention for all cardiac arrest victims.

Prioritizing the administration of epinephrine has led to other demonstrably more impactful interventions being delayed.[12] To address this, consistent with local protocol, the emphasis should be on high-quality uninterrupted CPR followed by appropriate interventions.

By sequencing the priority of interventions, it's likely that epinephrine, when administered, will be given when the patient is more receptive to its pharmacological impact: after the patient has adequate perfusion, resolution of underlying acidosis and with an adequate $EtCO_2$.

The RFD goal for this survivability tool is to emphasize the activities that are essential in the initial minutes of resuscitation and to subsequently defer epinephrine administration until priority treatments are realized. The RFD has seen an increase in survival-to-discharge as a result of this sequencing approach.

HOLISTIC APPROACH

There's no magic ingredient to successful cardiac arrest resuscitation. Although case review has shown increased ROSC rates associated with application of all of the RFD Cardiac Survivability Tools, the significant increase in survival-to-discharge is due to the implementation of the whole system rather than a single element.

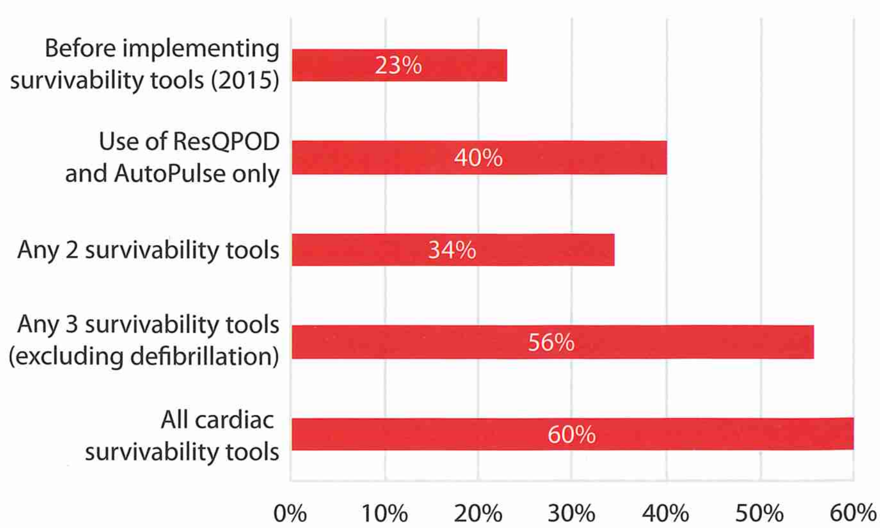
The RFD's system-based approach relies upon a strong quality improvement (QI) and training platform alongside one of the RFD's core values: teamwork.

The most impactful QI actions have come from the RFD establishing post-resuscitation feedback that alerts providers and department leadership to compliance with the RFD Cardiac Survivability Tools. This allows for focused assessment of each incident and aids in establishing training needs so that small course adjustments can be made on a regular basis.

CONCLUSION

So, let's be clear, what we have been taught isn't working! We have to stop doing what

Figure 1: Percentage of patients where ROSC was achieved



The ResQPOD ITD acts as a one-way valve which lowers thoracic pressure, creating a vacuum that pulls more blood back to the heart, increasing preload while decreasing intracranial pressure to allow for quality cerebral perfusion.

From an ergonomic and effectiveness perspective, heads-up CPR can only be performed with an automated CPR device and should only be performed with an ITD in place to maximize the pressure variant and cerebral perfusion.

we have always done. We need to ask, in no uncertain terms, does every single thing I do in the cardiac arrest setting improve neurologically intact survival. If not, why do we do it?

The RFD is hopeful that you've unlearned some of the things you were previously taught and are motivated to evaluate this new paradigm and how it could increase cardiac survivability in your community. JEMS

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HIGH-PERFUSION CPR

New technology dramatically improves cardiac arrest survival in Collierville, Tenn.

By **Joe Holley**, MD, FACEP, FAEMS

The ResQCPR System has been shown to dramatically improve cardiac output and blood flow to the brain and other vital organs during CPR.
Photos courtesy Joe Holley

Serving in the medical oversight role for nearly 30 EMS services in and around Memphis, Tenn., I have the challenging task of tailoring equipment and protocols to each site's population, budget and needs.

Collierville is a Memphis suburb, with a population of around 45,000. Its residents are relatively affluent and well-educated, and community education efforts have improved the frequency and quality of bystander CPR.

It's a perfect example of a small town that's done very well in improving survival from cardiac arrest, which is why I felt additional technology could take the town to the next level.

Collierville Fire and Rescue (CFR) is a full-time department with approximately 70 personnel. CFR provides life safety, fire protection and customer service to the community through the delivery of fire suppression, ALS, specialized technical rescue operations and other services.

Each year, CFR responds to an average of 3,500 calls, 70% of which are EMS-related, including around 40 cardiac arrest calls each year. The department maintains an average response time of 4 minutes 50 seconds to all incidents from five strategically located firehouses throughout the community.

All firefighters are cross-trained in EMS and are licensed as paramedics or Advanced EMTs (AEMTs).

Historically, the incidence of bystander CPR was good in Collierville, the result of years of community education and training. The town's EMS cardiac arrest protocol is comprehensive, including dispatch-assisted CPR instruction for 9-1-1 calls with immediate response by a fire apparatus that's followed quickly by a contracted ambulance service.

Two engines are dispatched to every potential cardiac arrest call, providing a response of 9-1-1 personnel trained at both the paramedic and AEMT level to each cardiac arrest call.

ADOPTING NEW TOOLS

Shortly after the ResQCPR System was FDA-approved in March 2015, I recommended it to the CFR EMS team as a way of further improving their survival rates.

The FDA had reviewed data supporting the approval of the ResQCPR System, including a randomized clinical trial that compared survival rates of 813 subjects who received standard CPR to 842 subjects who received CPR with the ResQCPR System.[1] The results showed that a larger number of subjects who received CPR with the ResQCPR System survived cardiac arrest long-term.

The ResQCPR System consists of two devices that are used together by trained rescuers while they're performing CPR: 1) the ResQPUMP active compression-decompression CPR (ACD-CPR) device; and 2) the ResQPOD impedance threshold device (ITD). The devices have been shown to significantly improve the patient's chances of surviving an out-of-hospital, non-traumatic cardiac arrest.[2,3]

I had been interested in the device combination since seeing demonstrations on its physiology in the laboratory. The device utilizes and enhances natural physiology, providing for better cardiac output and better cerebral blood flow.

Traditional CPR has a "push and relax" duty cycle, but the ResQPUMP—a handheld device with a suction cup that's placed on the patient's chest—actually allows the rescuer to pull up and actively re-expand the chest wall (i.e., "push and pull"). This ACD-CPR creates a vacuum in the intrathoracic cavity that increases blood flow to the heart and brain.

This vacuum is maintained and enhanced when used with the ResQPOD ITD in the airway circuit. As more blood is drawn back to the heart during the decompression phase, this enhanced preload results in a greater volume of blood flowing out of the heart (i.e., cardiac output) during the next compression.

The synergy of the two devices has been shown in studies to provide near normal blood flow during CPR.[4–6] By facilitating high-perfusion CPR, it's more likely patients who survive will be neurologically intact.

Real-time electronic guidance helps ensure accurate compression depth, lift height and compression rate.

TRAINING & IMPLEMENTATION

In spring 2015, CFR purchased six ResQCPR Systems. In conversations with department leadership, I conveyed that the science is supportive of the technology and that I was confident that the quality of CPR would be better than manual—or even mechanical—CPR.

Formal staff training was conducted over a period of one week. The ACD-CPR device is different from standard CPR, but it's fairly intuitive, and the ResQCPR System provides real-time, electronic guidance to the rescuer to help them accommodate for the differences.

A force gauge provides information on compression and lifting forces, while the metronome guides the rescuer to compress at the appropriate rate. Timing lights on the ITD can be turned on to cue rescuers on the proper ventilation rate minimizing the likelihood of hyperventilation. These features help promote high-quality CPR at all times.

After the initial training, the cardiac arrest protocol was revisited to determine if it needed adjustment. Changing the protocol was simple and straightforward. It was updated to make it clear that any time a patient was in cardiac arrest, the ResQPOD ITD was to be used along with manual CPR to improve perfusion. As soon as the ResQCPR System arrives on scene, the ResQPUMP is utilized with the ResQPOD.

In the first eight cardiac arrests, CFR had seven neurologically intact saves, which was remarkably better than what they'd had before.

RESULTS & SAFETY BENEFITS

Within 4–6 weeks from the time the devices were purchased, CFR staff were fully trained and the equipment was being used regularly.

Immediately after the teams started using the ResQCPR System, they experienced improved outcomes. Right off the bat, in the first eight cardiac arrests, CFR had seven neurologically intact saves, which was remarkably better than what they'd had before.

The one patient they weren't able to resuscitate had suffered a cardiac arrest while riding his bike, causing him to fall and sustain a serious head injury. Although CFR crews were successful in restoring his heartbeat, he eventually succumbed to his head injury.

The early successes created confidence among the CFR EMS staff that the technology worked, and their enthusiasm has remained high.

The CFR EMS chief was initially pretty skeptical about the ResQCPR System, but then he started getting calls from family members thanking them for saving their loved ones' lives. He told me, "I never got those before."

CFR has also noticed something unique when using the ResQCPR System. In the past, they never had cases of patients in cardiac arrest responding to them during the resuscitation. However, when using these two devices, they experienced some patients literally reaching their arms out to the crews or trying to pull out their endotracheal tubes despite being in cardiac arrest.

They've never had to deal with this before. It tells me that the brain is being perfused well enough for patients to respond, despite being in cardiac arrest. That's an encouraging sign.

As a result of patients experiencing these episodes of increased levels of consciousness, I added a new protocol for sedating cardiac arrest patients to prevent them from interfering with their treatment.

According to Pat McGrath, a paramedic lieutenant for CFR, the numbers support what the crews are seeing in the field. (See Figure 1.)

Prior to adopting the ResQCPR System, just 7% of patients where ROSC was achieved were discharged with normal neurological outcomes. After implementation, the number of neurologically intact patients climbed to 47%.

McGrath comments on this amazing difference, saying, "We have had some patients come by to see crews at the station. We know we have had a significant increase in saves."

In addition to improving outcomes, the ResQCPR system improves safety for the crews who, in the past, would perform CPR during transport. As everyone knows, doing CPR on the move is extremely difficult to do without interruptions and changes in depth, and can be unsafe for the rescuers, who traditionally had to perform CPR unbelted in the patient compartment.

The ResQCPR System allowed CFR to change their approach toward cardiac arrest: patients are no longer immediately put into the ambulance and are instead kept on scene.

By working the cardiac arrest on scene, crews have the best chance of getting the patient's heart going again. Transport is initiated once the patient is stable. While en route to the hospital, the airway is managed, medications are administered on board, and crews know the patient has been given the best possible opportunity to survive.

LESSONS LEARNED

There are three primary takeaways that we learned by implementing this technology:

1. ResQCPR is different than standard CPR. Crews had to learn a new way of performing CPR and understand the three important differences.

First, the rate is slightly slower (80/min.) than conventional CPR, allowing the heart to refill longer.

Second, you're actively lifting during decompression rather than just allowing the chest to relax on its own.

Third, you must use the ITD with ACD-CPR in order to optimize the intrathoracic vacuum and perfusion. Commitment to the training is critical to success. Crews may assume that if they're already good at CPR, they don't need to be trained on the system. However, if they don't learn how to use it correctly, they won't be taking full advantage of the improved perfusion the products provide.

2. You must first know how to do high-quality CPR before implementing these tools. If the quality of your CPR is poor today, you won't be gaining much of anything by adding these tools. But if your crews are already doing high-quality CPR (rate of 100–110, depth of 2 inches and compression fraction > 90%), these devices will help make things even better. Systems that aren't meeting those metrics need to focus on the basics first.

3. It's better to work the patient on-scene instead of attempting CPR in the back of a moving vehicle. It's virtually impossible to perform high-quality CPR safely in the back of a moving vehicle. CFR crews only transport after working the patient on scene using the ResQCPR System and getting a pulse back. If crews transport patients with ongoing cardiac arrest, the use of ResQCPR is discontinued. Ideally, patients transporting with ongoing cardiac arrest would be placed on an automated CPR device, however, CFR's current ambulance contractor doesn't utilize this technology.

CONCLUSION

The ResQCPR System, which is made up of two devices that enhance natural physiology, provides for better cardiac output and better cerebral blood flow during CPR, improving the patient's likelihood of surviving an out-of-hospital, non-traumatic cardiac arrest. Implementing ResQCPR in a community like Collierville, where high-quality CPR was already the norm, has helped significantly improve cardiac arrest survival rates. JEMS

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Figure 1: Annual ROSC rates (2014–2017*)