Data from the ROC studies showed that use of an impedance threshold device did increase survival with good brain function if chest compressions were performed at the recommended rate of about 100 per minute. Photo courtesy EMSA

RESUSCITATION GEMS

Resuscitation outcomes consortium (ROC) studies dig deep into the science of CPR

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It's been 50 years since the famous white paper "Accidental death and disability: The neglected disease of modern society" was prepared and released by the Committee on Trauma and Committee on Shock of the National Research Council of the United States National Academies of Sciences.

This watershed document opened the eyes of the American public to the 52 million accidental injuries that killed 400,000 Americans, referred as an "epidemic of modern society," uncovered serious deficiencies in the nation's emergency response system and called for corrective measures to stem what it referred to as "the leading cause of death in the first half of life's span."

The nation awakened and Congress and the medical community began to take action to correct the response and care deficiencies that existed, including the funding of training and equipment and working to establish integrated networks of trauma centers, medical helicopters and improved dispatch and communications capabilities.

It all made a significant impact on the horrific death toll that existed at the time.

So, what most often kills Americans today, 50 years later? Trauma? Cancer? Sepsis?

Today, no other major disease state still kills as many adults in the U.S. as sudden cardiac arrest.[1]

Remarkably, it's been more than 50 years since manual closed chest compressions paired with artificial ventilations were first described. Despite these five decades the overall survival rate, specifically neurologically intact, is still dismal in the majority of America's major metropolitan and rural areas. But tragically, survival among all victims of sudden cardiac arrest is far less than 20%, even in the best performing emergency services cities.[2] Moreover, despite a half century of research, the physiology of cardiopulmonary resuscitation (CPR) remains incompletely understood.

Since 2005, the National Institutes of Health has encouragingly prioritized and spent well over $100 million dollars in hopes of improving out-of-hospital cardiac arrest outcomes through research conducted by the Resuscitation Outcomes Consortium (ROC).

The ROC is comprised of North American cities with well-functioning emergency care systems such as Seattle, Pittsburgh, San Diego, Milwaukee, Vancouver, Ottawa and Toronto. Large multisite, multiyear studies have assessed:

1. 30 seconds vs. three minutes of CPR before defibrillation in initial rhythm of v fib patients;[3]
2. Sham (i.e., nonfunctioning) impedance threshold device (ITD) vs. active ITD (i.e., functioning)—commonly known as the ResQPOD;[4] and
3. 30 compressions to two ventilations (30:2) vs. continuous chest compression (CCC) with asynchronous ventilations.[5]

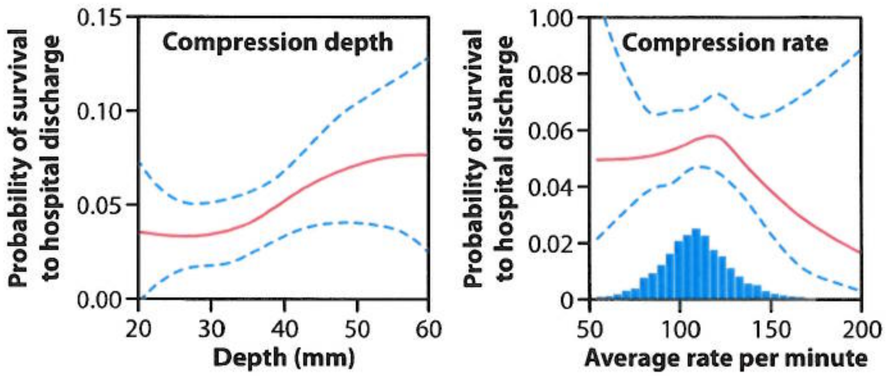
These studies, as well as others, were all neutral in their results, meaning no statistically significant differences were found between the treatment approaches to alter eventual survival outcomes.

A lot of attention in academic organizations has been given to what may or may not have gone wrong in the studies and what could have been done better. But scratch under the surface and you'll find there are many sparkling ROC gems to discover. These jewels aren't just interesting; they can save countless lives.

30:2 VS. CCC

Let's start with the most recent ROC sudden cardiac arrest study, which compared the 30:2

Figure 1: Range in compression depth and rate from the ROC PRIMED trial, and the effect each had on survival to hospital discharge rates[6,10,11]



compression-to-ventilation ratio—the current American Heart Association recommended guideline for adult CPR—vs. the newer concept of CCC with 10 asynchronous breaths per minute. The compression rate was 100 times per min in both groups and the ROC study involved nearly 20,000 patients.[5]

The primary outcome evaluated was survival to hospital discharge with good brain function. It was published in the prestigious *New England Journal of Medicine* and the results showed 7% survival with good brain function in the CCC group vs. 7.7% survival in the 30:2 group, though there was no statistically significant difference.

Does this mean it was a neutral study? Not so fast! The ROC investigators decided, because previous studies were plagued by CPR quality issues, to revisit the effect of CCC vs. 30:2 using an analysis based upon the question: Did the patients actually receive CCC or 30:2?

They used AED-captured data during CPR to perform a "per intended protocol" analysis of the real treatment delivered to patients. They found that just 52% (6529/12,653) of all CCC patients actually received CCC. And, only 33% (3678/11,058) of all 30:2 patients actually received 30:2.

These findings were more strikingly positive: 7.6% survival to hospital discharge with good brain function with CCC vs. 9.6% survival to hospital discharge with good brain function with 30:2.

These differences were highly statistically significant and provide solid evidence that there's a 2% increase in survival with good brain function by following 30:2.

The 2% increase seems small, but the significance becomes apparent when you do the math. The "lost" 2% of at least 350,000 sudden cardiac arrests per year in the U.S.[2] represents 7,000 additional lives being saved with 30:2 vs. CCC.

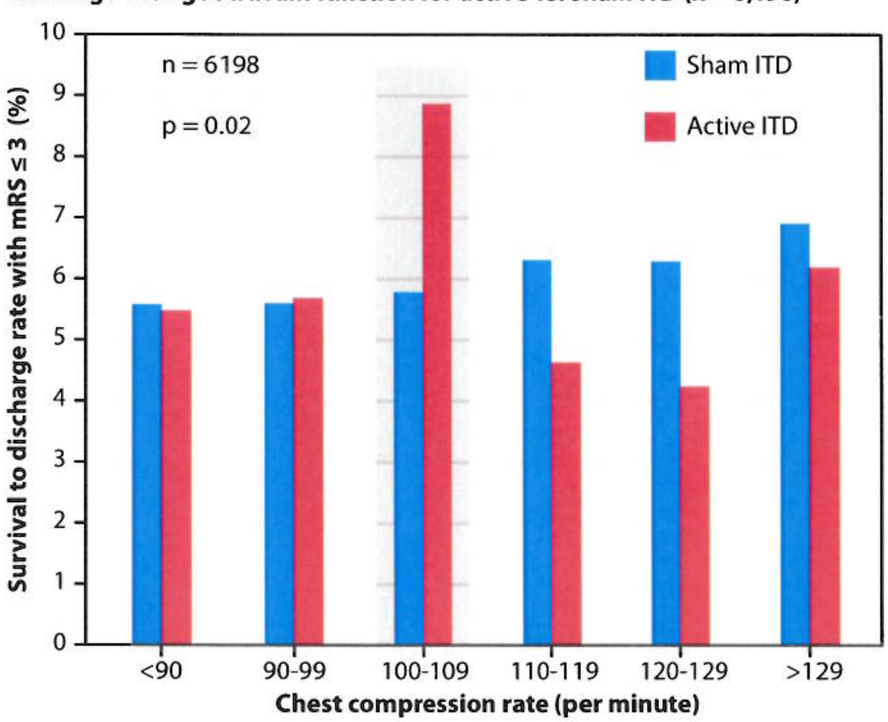
We may never know with absolute certainty the reason behind the results, but there are several solid physiological explanations.

1. The lungs serve as a large "sponge" for blood, which backs up during cardiac arrest. Two sequential breaths with 30:2 CPR being delivered fully inflates the lungs, thus forcing more blood forward and out of the lungs into the left side of the heart, helping to better refill the left ventricle before the next compression.
2. When the lungs are fully inflated periodically, the blood vessels dilate, reducing resistance to blood flow from the right side of the heart to the left, thereby improving circulation to the heart and brain. Too many breaths and too few breaths are bad for blood flow through the lungs but 30:2 has shown to be a good ratio.
3. The asynchronous breath delivered during a compression during CCC increases resistance to blood flow through the lungs and reduces circulation. This is because the lungs never are allowed to fully inflate, and thus the blood vessels are always partially constricted.[6–8]

An additional benefit of 30:2 may be that in the first few minutes of reperfusion after a prolonged downtime, the pauses in compressions may provide some protection again reperfusion injury. One recent study showed that with >12 minutes of untreated cardiac arrest in pigs, three intentional short 20-second pauses helps protect against reperfusion injury.[9]

Despite not knowing why 30:2 is better, careful analysis showed that it's better. It's *why* EMS should continue to teach and practice 30:2.

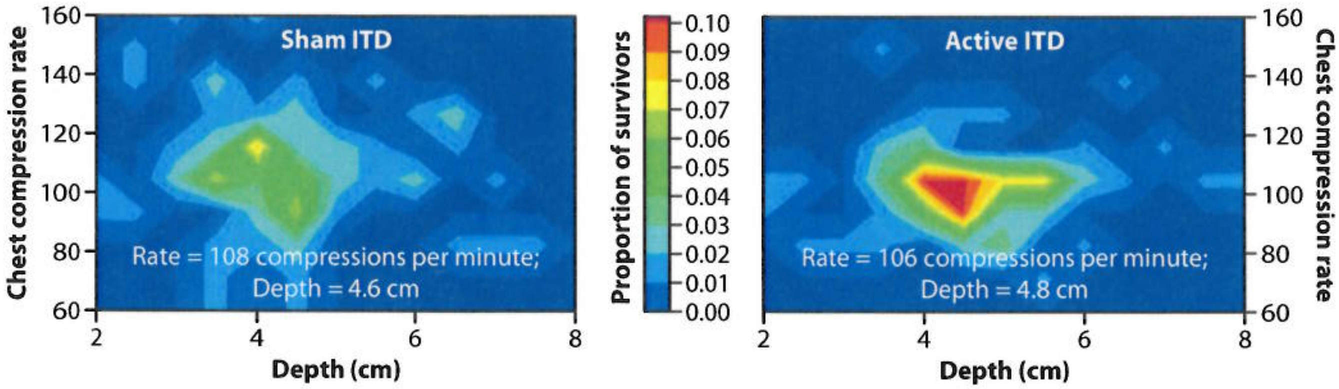
Figure 2: Effect of chest compression rates on survival to hospital discharge with good brain function for active vs. sham ITD (n = 6,198)[6]



TIME TO DEFIBRILLATION

There are other jewels from ROC, such as the study of 30 seconds vs. three minutes of CPR before defibrillation in patients with

Figure 3: The "sweet spots" for compression rate and depth needed to optimize survival with good brain function after cardiac arrest with and without an active ITD.[15]



an initial rhythm of v fib. This "analyze early" vs. "analyze late" study, known as the ROC PRIMED study, also simultaneously looked at a sham vs. active ITDs.[3]

The primary results from this study, which involved more than 8,000 patients, were also seemingly not statistically significant when looking at survival from any of the CPR approaches. It was actually stopped prior to its planned completion, based on the math that continuing it to full length wouldn't change the early results.

But wait! Like the 30:2 vs. CCC study, there were a lot of variables or "moving parts" involved, and with additional analysis of the data captured in the study, more jewels were discovered.

There was a wide range of compression rates and compression depths that actually occurred during the study and the effect this variability had on survival. (See Figure 1, p. 30.)[6,10,11] Rates and depths were captured by AEDs and sensors in many, but not all, of the patients.

When this recorded data was subsequently examined by the ROC investigators, it revealed that consistent, high-quality CPR was extremely difficult to provide, despite best efforts by EMS personnel.[10,11]

Survival was most typically correlated to chest compression depth of 4–6 cm (i.e., about two inches), with a rate between 80–120 compressions per minute. Remarkably, less than 1/3 of all patients in the study actually had the intended depth *and* rate.

It certainly seems that some sort of real-time feedback to ensure consistent chest compression rate and depth—and ideally, chest wall recoil—is critical in promoting the achievement and maintenance of truly high-quality CPR.

These feedback tools are designed to help curb the natural tendency of personnel to compress too fast and to deliver compressions that are too shallow, both without complete chest wall recoil over time. Without real-time feedback tools, it's extremely hard to consistently perform high-quality CPR.

And now, more than ever, we understand:

- >> High-quality CPR is critically important to achieving neurologically intact survival from sudden cardiac arrest;
- >> Hyperventilation during CPR is very common;
- >> Positive pressure ventilation directly correlates to reducing coronary perfusion pressure;[12] and
- >> Hyperventilation has been directly linked to fatal outcomes (in pigs, at least).[12]

With the ROC studies showing that CPR quality varies enormously in the real world, even when provided by highly trained rescuers, we know that poor CPR quality leads to poor outcomes.

ACTIVE ITD USE

The ResQPOD ITD was developed to increase blood circulation to the heart and brain during CPR.[6] If the survival analysis is limited to whether the active ITD was used or not, you might believe it's just an expensive dud. However, after studying the impact of active ITD use and correct compression rate, the ROC investigators showed that the active ITD did increase survival with good brain function if chest compressions were performed at the recommended rate of about 100 per minute. (See Figure 2, p. 30, which shows survival with good brain function was highest with the active ITD and compression rates of 100–109 per minute vs. a sham ITD.)[6]

Described initially by the ROC investigators and driven home by more recent analysis of the ROC PRIMED data conducted by several research teams, we see once again just how important high-quality CPR is for effective resuscitation.[13–15]

Using reverse engineering, one group of investigators compared every survivor with good brain function from the PRIMED study to known compression rate and compression depth data recorded.[11] They performed a contour plot analysis and, for the first time, discovered and described the true "sweet spots" for survival with good brain function. (See Figure 3.)[15]

Putting all the gems together, we believe if we compress the chest at a rate of 108 times per minute, compress the chest to a depth of 4.6 cm, avoid incomplete chest wall recoil and avoid hyperventilation, we can maximize survival in what can be termed "truly high-quality CPR." If using the ITD, slight changes of chest compression rate to 106 times per minute and chest compression depth to 4.8 cm is the right technique.

LOOKING AHEAD

The roadmap is getting clearer for optimal manual chest compression resuscitation:

1. Start CPR with 30 chest compressions to two ventilations;
2. High-quality manual CPR means a rate of approximately 105 compressions per minute, with a depth of approximately two inches while making sure to allow complete chest wall recoil; and
3. Use of an ITD.

EMS systems incorporating these specific steps, which were validated through peer-reviewed, published research, could improve survival with good brain function up to an additional absolute 8% for witnessed sudden cardiac arrest and for everyone in sudden cardiac arrest by up to as much as 6%. With over 200,000 witnessed out-of-hospital sudden cardiac arrests per year in the U.S.,[2] that means up to 12,000–16,000 more people surviving with good brain function.

These are just the results from a few important studies involving standard, manual chest compression in patients kept in the standard supine position for resuscitation. Even more progress is on the way. Stay tuned! JEMS

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