# The ART of Resuscitation

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## Introduction

In 2007, the University of California San Diego (UCSD) Medical Center instituted the novel resuscitation program known as ART, or Advanced Resuscitation Training. Not simply a replacement for traditional training courses, ART is a template for a new strategy of resuscitation oversight that can be applied in other institutions.

ART has three main goals:

- To prevent the preventable
- To resuscitate the resuscitatable
- To recognize the futile

With this in mind, the clinical leadership at UCSD, under the direction of Resuscitation Director Dan Davis, MD, has built this innovative, lifesaving program. ART has succeeded in significantly improving outcomes by increasing both survival and the rate of good neurological outcomes in the inpatient population while decreasing the overall incidence of arrests through surveillance and implementation of a rapid response team. This issue of *Code Communications* outlines the fundamentals of the ART program specifically surrounding CPR quality and incorporating advanced technology, as well as highlighting some of the clinical success the UCSD team has seen. The next issue will focus on preventing arrests and the use of the rapid response team and how UCSD has employed metrics to increase the acceptance and utility of the rapid response team.

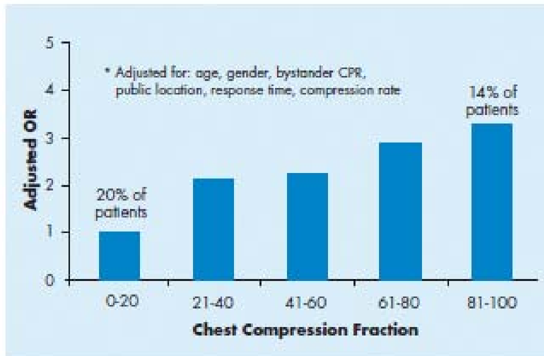
## ART Defined

ART is based on the premise that optimal cardiac arrest resuscitation is directly influenced by high-quality CPR. Data from published literature suggest that the average survival to hospital discharge from cardiac arrest in the U.S. is about 18%.[1] Historically, the CPR being performed in the hospital has not been adequate. A key aspect of the ART training is performing compressions from the moment of arrest until ROSC (return of spontaneous compressions). To achieve high-quality CPR, you need to:

- Stay on the chest.
- Do continuous compressions. Do not take breaks to ventilate.
- Push hard. Push deep—as deep as you can.
- Make sure you have good recoil.

One measure of CPR quality is the CPR fraction, the percentage of time that compressions are delivered during resuscitation. A 2009 pre-hospital study found that survivability dramatically increases if the CPR fraction is 81% to 100% (Figure 1).[2] This study concluded that only 14% of patients were receiving good compressions, with the provider staying on the chest more than 80% of the time. For 20% of patients, the rescuers stayed on the chest only 20% of the time at best.

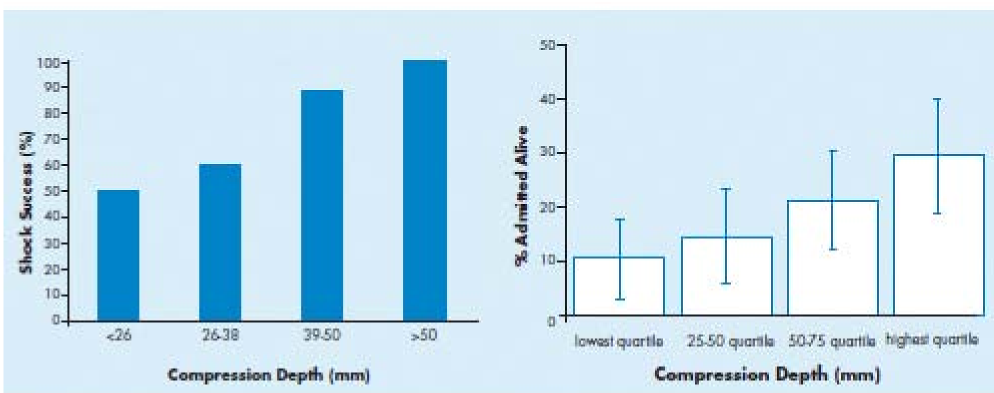
*Figure 1 –Stay on the Chest!*




Based on: Christenson J, et al. *Circulation*. 2009;120:1241–47.

Two studies from 2006 demonstrate the importance of deep compressions when it comes to survivability, as shown in Figure 2.[3,4] The ART program emphasizes a balance between pressing deep as well as achieving good recoil. Full recoil is imperative to allow blood flow to return to the heart and support of coronary perfusion pressure. Without good recoil, the intrathoracic pressure will be very high and perfusion compromised. The team at UCSD took this data into account as well as that from several other studies looking at CPR quality when developing the ART program.

*Figure 2 – Compression Depth Matters.*




Edelson DP, et al. *Resuscitation*. 2006 Nov;71(2):137–145.

Based on: Kramer-Johansen J, et al. *Resuscitation.* 2006;71:283–292.

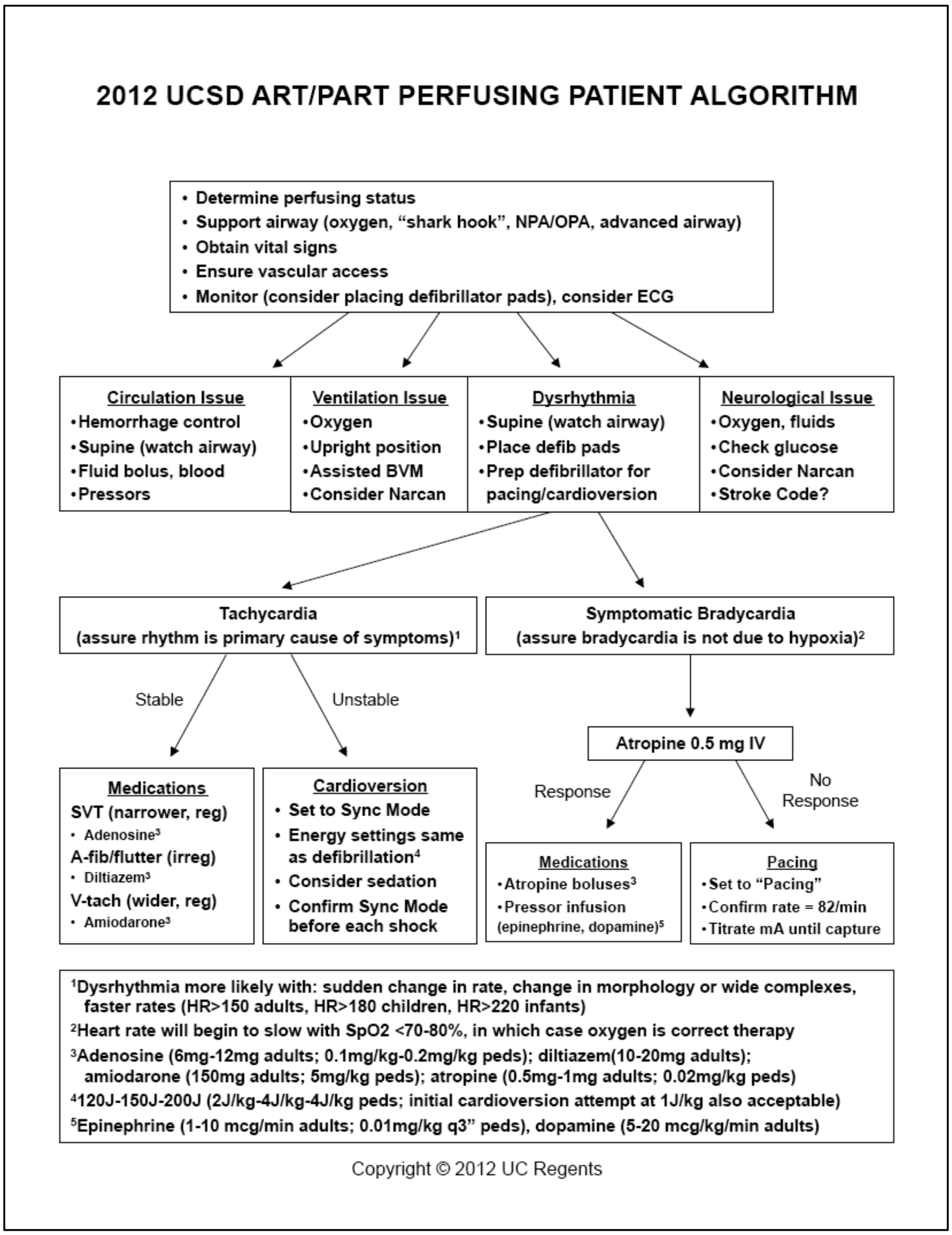
## An Adaptable Model

ART is different than the traditional ACLS (advanced cardiac life support) algorithm. At UCSD, all physicians, nurses, house staff, and nurse assistants receive specific training in either ART or BART (basic resuscitation training) for non–critical care providers. Training is provided by UCSD-trained instructors in a simulation center at the affiliated medical school, allowing the staff to come in and do actual Code

Blue simulations with other members of the team. Figure 3 shows the ART/PART (pediatric advanced resuscitation training) algorithm. The patient perfusion piece is similar to that of ACLS training; however, the rest of the algorithm is unique to ART.

The ART model is flexible and adaptive, and data collection is critical to success. Each month, the code team at UCSD meets to evaluate every Code Blue and every rapid response, and then follows up to address any educational components that are missing. Therefore, the ability to track and review each and every code is paramount.

*Figure 3 - ART: Advanced Resuscitation Training. PART: Pediatric Advanced Resuscitation Training*



## Integrating Technology

Incorporating new technology into a time-critical environment can be intimidating. The team at UCSD uses ZOLL defibrillators and electrodes. The reason for making this decision was the need for a device that provided real-time CPR feedback, universal end-tidal $CO_2$ monitoring, and the filtered ECG, made possible with See-Thru CPR® technology. In addition, the ART program integrates technology to provide resuscitation metrics that can identify needed performance improvements. The UCSD staff evaluated the product offerings and prioritized these features when choosing a defibrillator/monitor.

Additional manufacturers in this field, such as Philips and Physio-Control, have alternative capabilities; it is important to evaluate the equipment options in terms of the priorities at the institution. What works for one facility may not be the optimal solution for another. After making a purchasing decision, it is important to understand the role the technology will play and how to ensure all users feel comfortable in operating the equipment.

## Improving CPR quality

*Figure 4 - Screen display showing CPR Dashboard™*


The ART protocol recommends compressions of at least two inches of depth or deeper if the patient's chest will allow. In addition, full recoil is very important to ensuring good perfusion.

Consider whether you are able to provide your staff doing chest compressions with feedback on their exact rate and depth. If not, it's difficult to ensure that they are doing high-quality CPR, no matter the amount of training. The defibrillator and CPR sensor used during codes at UCSD show the staff the actual rate and depth displayed on the screen in real time. This enables the code leaders to provide feedback to the team member performing CPR and to rapidly identify staff fatigue and make appropriate substitutions. The screen display (Figure 4) shows that depth is good, and the rate is approximately 127 compressions per minute. The pink diamond is the performance perfusion indicator, or PPI. If the diamond is completely full, it indicates that the rescuers are staying on the chest and both depth and rate of compressions are within current guidelines. The rectangular bar is an indicator of recoil. If the bar is full, the rescuer is coming off the chest between each compression to achieve good recoil.

### *Filtered ECG*

There are many reasons why compressions are stopped in the hospital environment—intubation, line placement, checking to see if there is an underlying rhythm—just to name a few. Pausing for too long directly impacts perfusion. In fact, data suggest that pauses should be less than 10 seconds; therefore incorporating technology that can help minimize these pauses is important.

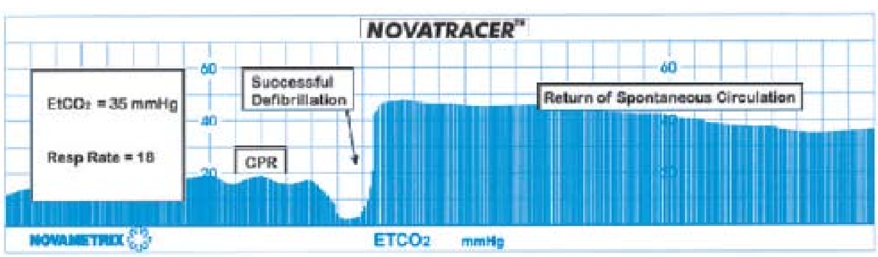
Typically, when performing CPR, the ECG is distorted by the CPR artifact, so it is necessary to stop compressions in order to see the patient's underlying rhythm. The filtered ECG allows the clinician to visualize the patient's underlying rhythm while still doing compressions because it filters out much of this artifact. Therefore, when compressions are stopped to confirm a rhythm or to perform a pulse check, the pauses are much shorter. In Figure 4, the ECG filter is operating even though CPR is in progress.

### *The Role of End-tidal $CO_2$*

The end-tidal $CO_2$ ($EtCO_2$) level is one of the main factors used by UCSD staff to help determine the return of spontaneous circulation (ROSC). The role end-tidal $CO_2$ plays in a resuscitation event has continued to grow as more related data have come in. The American Heart Association (AHA) acknowledged the value of end-tidal $CO_2$ in the 2010 Guidelines by assigning a Class 1, LOE A recommendation for the use of continuous waveform capnography as the most reliable method of confirming and monitoring placement of an endotracheal tube.[5] In addition, the AHA gave a Class IIb, LOE C recommendation to the use of capnography in intubated patients to monitor CPR quality, optimize chest compressions, and detect ROSC during chest compressions or when the rhythm check reveals an organized rhythm.[5]

Figure 5 shows the capnography trace of a patient who is in cardiac arrest. During CPR, the end-tidal $CO_2$ level is only at 18 mmHg. According to the ART algorithm, this patient is dead. Typically, there is a dip in end-tidal $CO_2$ levels when CPR is paused to defibrillate. Upon restarting CPR, the $EtCO_2$ level climbs up into the forties. This is a very positive sign. The clinicians would make certain that the level is maintained, then hold compressions and watch to be sure that the level stays in the forties, as well as monitoring the ECG.

*Figure 5 - Capnography waveform*



One key point that is emphasized in ART is the importance of treating the patient and not the monitor. For example, in Figure 6, the pulse ox reading is 72%, the heart rate is 72, and it looks like the patient has some QRS complexes. Based on this screen, it would be natural to infer that this patient is perfusing and has a heart rate of 72—a living patient. However, notice that the end-tidal $CO_2$ level is zero, so this patient can't possibly be alive. In fact, the pulse oximeter sensor is on an Ambu mask. This underscores the value of taking into account all of the pieces of technology available.


*Figure 6 - Treat the patient not the monitor*

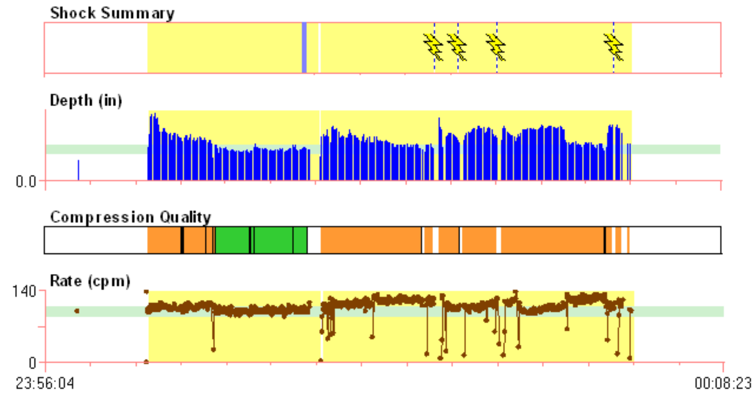
*Debriefing*

What happens after a code in your institution? What data do you discuss? How frequently do these discussions happen? What information do you wish you had to make these discussions more fruitful? A benefit to implementing advanced technology is the access to specific data after an event that can be used to educate, improve training, and evaluate the effectiveness and outcomes of an initiative. At UCSD, the capabilities of the defibrillator and electrode system provide granular information during the code and after it, such as each individual chest compression, length of time off the chest, when a shock was delivered, and ECG throughout the event. When implementing the ART program, the UCSD team developed a formal mechanism to retrieve and analyze data. Specific data points that are discussed during a debrief include:

- rhythm confirmation
- chest compression fraction (percentage of arrest time in which compressions were performed)
- compression rate and depth
- ventilation rate
- end-tidal $CO_2$ values
- pre- and post-shock pause duration
- perfusion chest pause duration
- appropriate defibrillator utilization

The ZOLL R Series® Monitor/Defibrillator and OneStep™ Complete Electrodes have the ability to provide CPR quality data, including the rate and depth of each compression during the code. The information in Figure 7 is an example of CPR data the code team is able to review after each event. This patient received three shocks in a row. In addition, the clinician who was administering CPR started getting tired, so the CPR delivered was no longer high quality; the depth fell below two inches and the rate began to slow. There was a brief gap when CPR providers switched. During the post-code debrief, the code team would analyze this switch to make certain the time off the chest did not exceed 10 seconds. After the switch, it was time to deliver a shock. The defibrillator was charged while CPR was being performed, thanks to ZOLL technology. Once charged, CPR was paused and the code leader confirmed a shockable rhythm. Then the charge was delivered and the code team immediately restarted CPR while the defibrillator was being charged again. The CPR provider stayed on the chest until the team was ready to defibrillate. Off the chest; confirm rhythm; charge delivered; back on the chest. This level of detail is key to debriefing after a code because the team is able to identify areas of improvement and work with the staff to make appropriate changes.

*Figure 7 - CPR data collected from the ZOLL defibrillator code record*

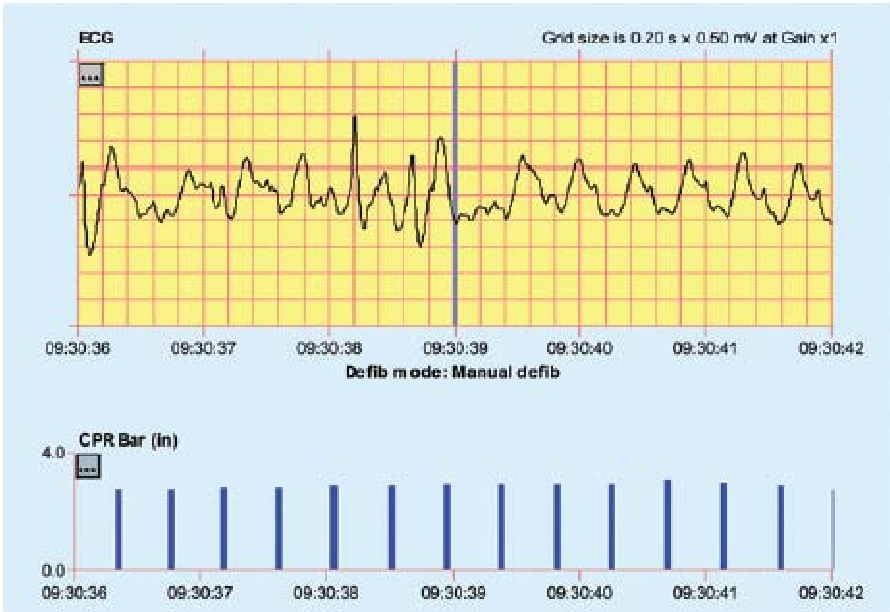



Because of the ability to document every event during the code; the UCSD team is able to review second-by-second data on the ECG strip. UCSD is a teaching institution and the code teams switch every month. The exception is the code nurses, who do not switch on the code teams. With the information available, there is ample opportunity to educate in the post-code debrief. It is easy for the staff to have this discussion: "Did you realize this person was PEA (pulseless electrical activity) and we were shocking an unshockable rhythm?" This type of information is invaluable from an education and teaching standpoint.

The graphs in Figure 8 are typical examples of the second-by-second data available for discussion during a post-code review. In the post-code debrief, the code team would discuss the fact that the patient was in V-fib (ventricular fibrillation) and that the CPR was good, with a depth of more than two inches and rate of approximately 130 compressions per minute. As CPR continued, there was a change in the patient's rhythm. This is followed by a long length of time where CPR was halted. The code team would want to understand why CPR was stopped. This patient was pregnant and compressions were stopped in order to perform a C-section.

The code team can then go back and make informed decisions regarding training and process improvement as a result of the amount of specific data at their disposal. For each code they can answer the following questions: When did we deliver a shock? How long did it take us to get back on the chest after the shock? How was our CPR quality? Were we compressing too fast? Not pushing deep enough? What could we have done better? Ultimately, it is very hard to provide the tools and training to improve patient outcomes from sudden cardiac arrest without being able to go back and review what has happened in detail.

*Figure 8 - Second-by-second data for post-code debriefing*



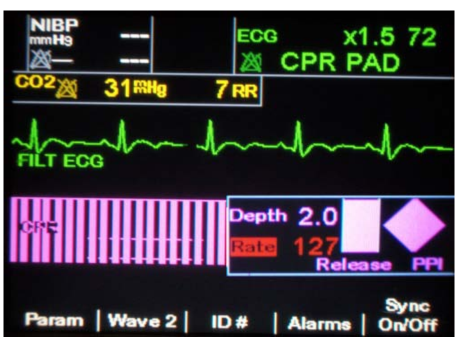

## Pulling It All Together

In Figure 9, you see four examples of an ECG and information available on the defibrillator throughout an event. The FILT ECG trace is the filtered ECG. Looking at Screen A, you see that the patient is in V-fib arrest and that the end-tidal $CO_2$ level is only 16 mmHg. In the ART algorithm, the UCSD clinicians are looking for an end-tidal value between 35 mmHg and 45 mmHg as an indication of ROSC. If the value is below 20 mmHg, this person cannot be considered alive. This patient is not doing well, but the CPR is high quality, as indicated by the depth of two inches and rate of 127 compressions per minute. At this time, the decision would be made to continue CPR and to treat the patient based upon the information available.

*Figure 9 - Screen displays from a ZOLL defibrillator*


*Screen A*


*Screen B*




*Screen C*


*Screen D*

In Screen B, the monitor is showing the ECG after the patient has received a shock. We see some identifiable QRS complexes. In the ART algorithm, this patient is still dead because the heart rate is less than 40. This is also confirmed by the end-tidal $CO_2$ value of 16 mmHg. If this patient had return of spontaneous circulation, the end-tidal $CO_2$ level would be greater than 25—hopefully, climbing up into the thirties. Based on this information, the UCSD clinicians overseeing the code would tell the team to continue CPR.

In Screen C, there is a different rhythm, and the end-tidal $CO_2$ value is at 31 mmHg. At this point, the team would want to do a pulse check. The code leader would ask the team to find a pulse point; CPR would not be stopped until everyone is set. Once everyone is set, compressions would be held. If they feel a pulse and continue to see the end-tidal $CO_2$ holding, this person is alive. However, if the pulse begins to weaken, someone would immediately resume CPR.

In Screen D, compressions are being held for a pulse check. The pulse ox waveform correlates with the ECG. In addition, there is perfusion and the end-tidal $CO_2$ level is being maintained in the thirties. This person is alive. This is an example of how all of the pieces of integrated technology factor into the picture during a code. While incorporating new technology can be intimidating, there is tremendous value in finding what works for a hospital/medical center and investing in the right training to ensure everyone is aligned and knows their role and responsibilities during a code.

### What ART Has Meant for UCSD

As with any initiative, it is important to determine the value of ART and to evaluate the results that the UCSD team has seen since its implementation. A major emphasis of the program has been the role high-quality CPR plays in resuscitation events and the link between time on the chest and patient outcomes. At UCSD, clinicians are on the chest 91% of the time, as compared with the national average of 60% (Figure 10). One of the reasons the percentage of time on the chest is greater than the national average is due to the See-Thru CPR technology on the R Series defibrillator, enabling the clinician to visualize the patient's underlying rhythm while still doing compressions.

UCSD staff compression rates average out to 123 compressions per minute and average compression depth is 2.6 inches. The advances in the defibrillator and electrode allow clinicians to monitor compression rate, depth, and recoil in order to make immediate adjustments if they begin to notice fatigue or inability to continue to deliver high-quality CPR. Another important statistic is pre- and post-shock pause time. The average pre-shock pause at UCSD is 2.6 seconds, and then it takes an average of 3.6 seconds after the charge is delivered to resume CPR. These results are continually being monitored in the CQI (continuous quality improvement) data. Additional data that is measured and analyzed include the length of time needed to do a perfusion check, approximately 4.3 seconds. Ventilation rate is an average of 9.7 per minute and end-tidal $CO_2$ levels average out to 15.3 mmHg.

*Figure 10 - UCSD CPR Statistics*

| **Results** | |
|---|---|
| Chest compression fraction | 91% |
| Compression rate | 123/min |
| Compression depth | 2.6 inches |
| Pre-shock pause | 2.6 sec |
| Post-shock pause | 3.6 sec |
| Perfusion check | 4.3 |
| Ventilation rate | 9.7/min |
| $PetCO_2$ | 15.3 mmHg |

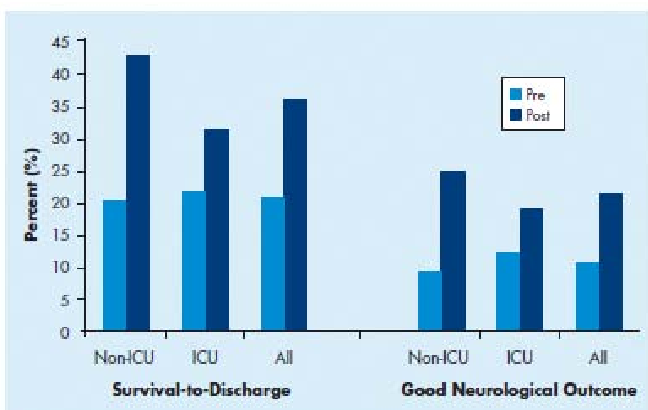
### Arrest Etiologies

The majority of codes at UCSD are patients that go into respiratory distress prior to showing actual cardiac issues. Data from the UCSD team have documented that 80% of non-ICU arrest victims demonstrated signs of deterioration up to five hours before cardiopulmonary arrest occurred. Early medical intervention to treat the predominant warning signs of hypoxia and hypotension are paramount in reducing the number of unplanned patient admissions to the ICU[6]. When the ART program was implemented in 2007, 45% of arrests were respiratory arrests. There was a need to educate the UCSD staff about how patients code and what to look for. Most of the rapid response calls are for respiratory issues, and since implementing the ART program, respiratory arrests have dropped down to approximately 20%.

### Impact on Patient Outcomes

The bar charts in Figure 11 compare the survival-to-discharge and good neurological outcomes data pre-ART training versus post-ART training. The results are clear; there has been a significant increase in survivability and good neurological outcomes since the implementation of the program. One particular point of pride for the UCSD team is the data from the non-ICU setting. The patients in the ICU are really sick, and there isn't always a lot anyone can do to predict whether or not they are going into cardiac arrest. To summarize the results during the five years since implementing the ART program, from 2007 through 2012, more than 250 lives have been saved. In addition, when patients die unexpectedly there is a charge of $50,000 to the hospital, so there has also been a monetary savings.

*Figure 11 - Comparison of outcomes pre- and post-ART outcomes*




### The Bigger Picture

When compared with the mortality rates for all of the hospitals in San Diego, UCSD has the lowest rate in the area (Figure 12). When compared with all of the teaching hospitals in California, UCSD is at the very bottom for mortality (Figure 13). These results are not going unnoticed. The ART program has been designated as a Best Practices Model by the Joint Commission and recognized as a Best Patient Safety

Initiative by both the National Association of Public Hospitals and the University of California Regents. Recently, the UCSD team received a Quality Leadership Award from the University Health System Consortium based on rapid improvements in overall mortality and patient safety and a top-five ranking in overall quality of care. The greatest achievement, however, is that observed mortality at UCSD is 38% below expected values, leading to the medical center's recognition as one of the safest hospitals in the county, state, and country.

*Figure 12 - UCSD mortality rate compared with all San Diego Hospitals*

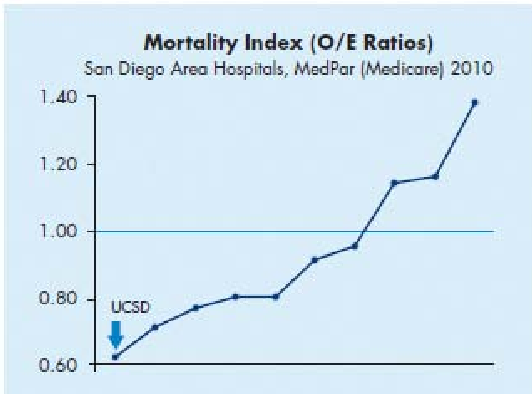
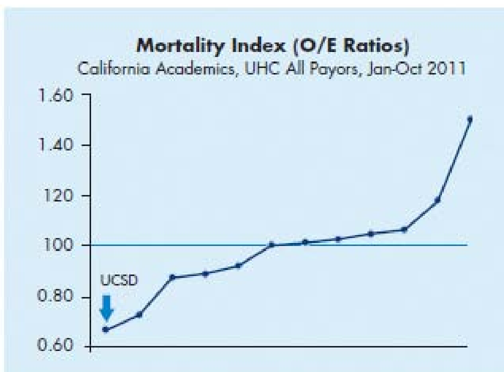



*Figure 13 - UCSD mortality rate compared with all California teaching hospitals*




## What can you do to find out more?

This article has highlighted some of the fundamentals of the ART program, specifically addressing CPR quality, integration of technology, and the resulting patient outcomes. However, this program is multifaceted and involves comprehensive training. The team at the UCSD Center for Resuscitation Science actively works with other institutions to help implement the ART program and replicate its results in both the hospital and pre-hospital settings. There are several ways to become involved or participate in an upcoming ART workshop. If you are interested, please visit: http://health.ucsd.edu/medinfo/training/crs/Pages/default.aspx.

## References


[1]Nadkarni VM, et al. *JAMA*. 2006;295:50–57.
[2]Christenson J, et al. *Circulation*. 2009;120:1241–1247.
[3]Edelson DP, et al. *Resuscitation*. 2006 Nov;71(2):137–145.
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[5]Neumar R, et al. *Circulation*. 2010;122(suppl 3):S729–S767.