PHILIPS

Q-CPR™ Measurement and Feedback

Application Note

Introduction

Consider the following:

- Research demonstrates that the quality of cardiopulmonary resuscitation (CPR) has a direct effect on survival rate and patient outcome from cardiac arrest.
- Research also indicates caregivers, on the whole, often do not perform CPR within established guidelines associated with compression rate and depth, duration of *no compression* activity (or "hands-off" time), and ventilation rate.

These statements relate directly to the need to establish a higher level of CPR quality <u>and</u> embrace appropriate tools and techniques to achieve that level. Q-CPR™ measurement and feedback technology by Laerdal represents one such option and is the focus of this application note. Specifically, this note:

- provides an overview of studies showing why Q-CPR could be valuable to any BLS or ALS caregiver performing CPR and, as a result, could positively influence patient outcome and survival from sudden cardiac arrest and
- describes how Q-CPR can provide timely feedback on compression and ventilation activity during CPR.

CPR: A Brief Historical Look

Modern CPR, with the establishment of mouth-to-mouth ventilation and closed–chest cardiac compression steps, has been in existence since the late 1950s and early 1960s. It is a critical link in the American Heart Association's (AHA) 'Chain of Survival'.[1] Related standards and guidelines for compression and ventilation were published over 30 years ago[2] and have been updated many times, most recently in 2000.[3,4] The importance of well-performed bystander CPR has been demonstrated to be a determining factor in survival from sudden cardiac arrest;[5] however, survival remains low.

There are clear indications that CPR is a weak link in the chain and there is need for improvement in the timing, efficiency, and overall quality in performing CPR.

Unfortunately, the BLS rescue breathing and chest compression skills are not always mastered or adequately retained by laypeople, as well as many healthcare professionals.[6,7] Also, CPR parameters in actual practice have not been routinely measured and, therefore, the quality of CPR performed in the field has not been known.[8]

Assessing CPR Quality

Good CPR involves early intervention that provides:

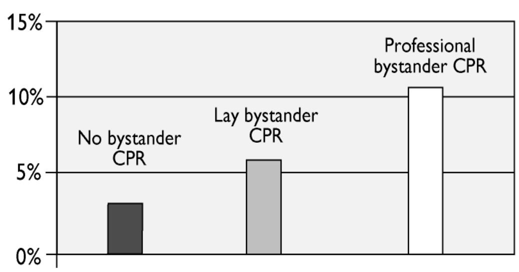
- chest compressions at the correct depth and rate, with minimal interruption, and
- ventilation at the correct rate and volume.

A look at the following studies establishes why the quality of CPR is important and the current state of compliance with CPR performance guidelines.

Study 1 - Impact of CPR

First, it is safe to say that CPR is a powerful intervention and the sooner it can be performed, the better. In a 12-year study from the Swedish Cardiac Arrest Registry and Herlitz et al.[9] involving over 17,000 patients with bystander-witnessed cardiac arrest, lay bystander CPR doubled the survival rate at one month (6.2%) and health care professional bystander CPR more than tripled the survival rate (10.8%) compared to no bystander CPR (3.1%), as depicted in Figure 1.

Figure 1 - *Patient survival rate doubles and triples!*

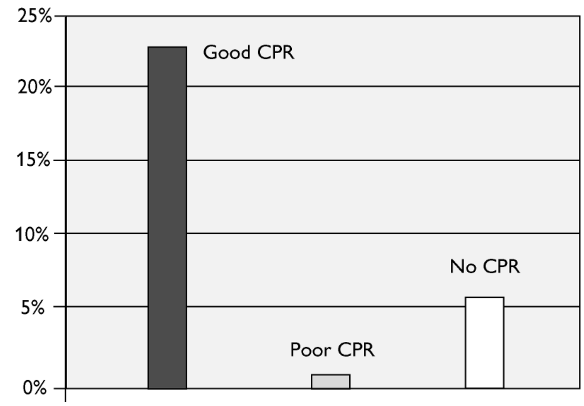


The importance of CPR quality is demonstrated in the next three studies – the first involving bystanders and the others professional out-of-hospital personnel.

Study 2 - Quality of Bystander CPR

Wik et al.[10] evaluated the influence of the quality of bystander CPR on the outcome of out-of-hospital cardiac arrest victims and determined that good bystander CPR was linked to a higher proportion of patients who left the hospital alive (23%) compared with poor CPR (1%) or no CPR at all (6%), as shown in Figure 2. There was no significant difference between poor CPR and no CPR. Good CPR was defined as a palpable carotid or femoral pulse and intermittent chest expansion with inflation attempts.

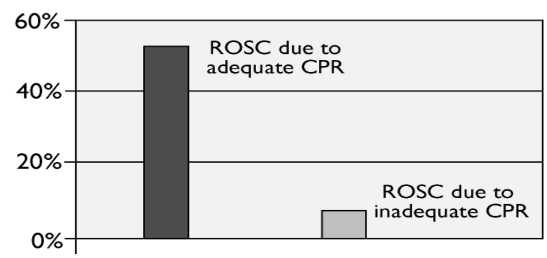
Figure 2 - *Good CPR increases survival rate!*



Study 3 - Quality of EMT CPR

Ko et al.[11] examined the quality of out-of-hospital CPR by reviewing automatic external defibrillator (AED) records and survival for out-of-hospital cardiac arrests. They judged CPR quality as adequate in 15 arrests (29%) and inadequate in 37 arrests (71%). Adequate CPR was based on noticeable deflection of the ECG with chest compressions, the actual number of chest compressions delivered per minute, and the continuity of prehospital CPR at the scene and during transport. For patients who received adequate CPR, there was a higher rate of return of spontaneous circulation (ROSC) at the scene (53%) compared to patients receiving inadequate CPR (8%), as illustrated in Figure 3. The survival to hospital discharge results were similar.

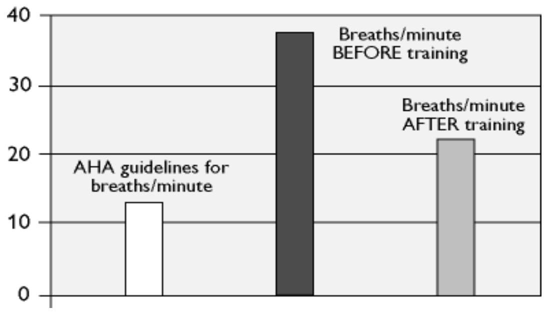
Figure 3 - *Adequate CPR leads to higher ROSC!*



Study 4 - Quality of Ventilation

Aufderheide et al.[12] studied ventilation rate administered by EMS personnel to 13 patients and found an average of 30 breaths/min. compared with AHA recommendations of 12-15 breaths/min., even after CPR retraining, as shown in Figure 4. They also reported that hyperventilation in a porcine cardiac arrest model resulted in increased positive intrathoracic pressures, decreased coronary perfusion, and decreased survival rates.

Figure 4 - *Ventilation rates exceed guidelines!*



Aufderheide et al. also concluded that their study findings have "significant implications for the interpretation and design of resuscitation research, CPR guidelines, clinical practice, and development of future CPR devices, and EMS quality assurance."

Addressing CPR Quality Improvement

The aforementioned studies suggest the need for tools and techniques to assist in the delivery of quality CPR to improve patient outcomes. To address this need, a number of studies have examined options for improvement that go beyond established classroom training techniques. One option that has shown great potential is audible or voice feedback, as demonstrated in the following manikin studies.

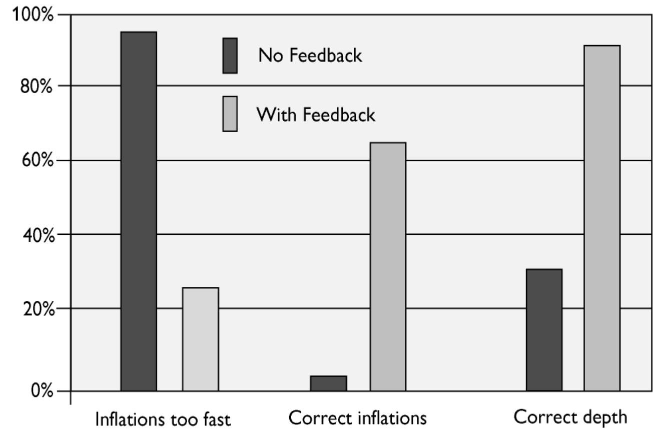
Study 1 - Audio Feedback Impact on CPR by Paramedic Students

Wik et al.[13] determined that an automatic voice-based manikin feedback system (developed by Laerdal - Stavanger, Norway) could be used to improve the quality of basic life support performed by two groups of paramedic students, without the presence of a CPR instructor. Group 1 started without audio feedback and performed poorly. Then, they demonstrated a significant improvement during the first 3 minutes of CPR with feedback in the following categories:

- too fast inflations (reduced from 94 to 25% of the time),
- correct inflations (increased from 2 to 64%), and
- correct compression depth (increased from 32 to 92%).

Figure 5 illustrates these findings.

Figure 5 - *Feedback improves ventilation and compression quality!*



Group 2 started with feedback, attaining a similar performance to Group 1 and maintaining CPR improvement even AFTER the audio feedback was turned off.

Study 2 - Audio Feedback Impact on CPR by Nurses

Handley et al.[14] concluded that, when using the same audible feedback system Wik et al. used in their study, a group of nurses receiving feedback were significantly better than a control group (who received no feedback) at performing inflations and achieving the correct depth of chest compressions. The authors concluded that CPR skill retention is a problem and suggested that incorporating an audio feedback system into a defibrillator could lead to better CPR performance.

Study 3 - Audio Feedback Impact on CPR by Prehospital Personnel

Hostler et al.[15] demonstrated that the voice-assist manikin (VAM) feedback system, when used by prehospital personnel (EMT-B, EMT-P, and PHRN), attenuated the degradation of compression and ventilation performance over a 3-min. period, as presented in Table 1.

Table 1 - *Feedback prevents performance decay!*

Variable	VAM Feedback	30 secs.	60 secs.	120 secs.	180 secs.
Correct inflations (mean%)	ON	61.3	57.3	59.8	58.8
	OFF	70.6	57.6	51.8	47.9
Correct compressions (mean%)	ON	56.5	60.0	68.1	68.0
	OFF	56.0	53.1	52.1	48.8

Study 4 - Audio Feedback Impact on CPR Skill Retention

Wik et al.[16] evaluated the retention of CPR skills 6 months after training of lay responders on a VAM feedback system. The initial training improved all variables; however, when tested again at 6 months without feedback, performance dropped back to the pre-training level. Then, when retested with the feedback system turned on, both the compression and ventilation performance returned to the level immediately after training. In a subsequent paper, the same authors[17] retested the trainees' skills after 12 months and found the same effect, concluding that subjects trained with computer-based voice advisory feedback performed CPR with no deterioration in feedback-supported performance at 12 months.

CPR Quality Improvement and Education: A Focused Solution

At this point, we can conclude:

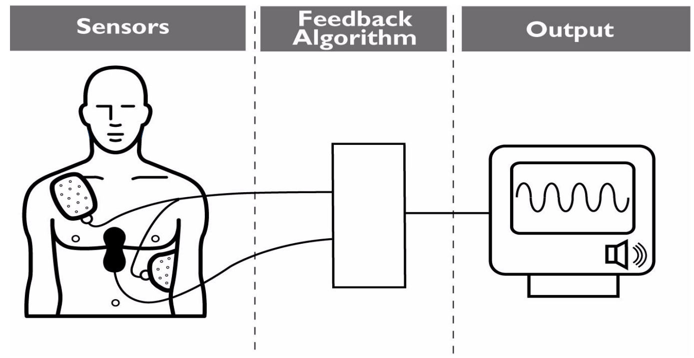
1. the quality of CPR is important and that it affects patient outcome (survival),
2. current CPR quality and non-compliance to established guidelines should be of great concern, and
3. implementation of tools to assist in the delivery of CPR makes sense.

Laerdal Innovation

As a world leader in CPR training and therapy solutions, Laerdal is focused on implementation of quality CPR support. They established the Sister Research Program in 1998 to improve patient therapy and obtain better outcomes. CPR quality and efficiency have been a primary program initiative, and automated verbal and visual feedback has become a critical technological output from the company's efforts, as utilized in the four studies just presented. Essentially, as illustrated in Figure 6, they have developed the capability to:

1. measure CPR performance (through appropriate sensors),
2. find the gap between actual and correct CPR (through a feedback algorithm), and
3. give verbal and visual feedback.

Figure 6 - CPR measurement and feedback technology



Some of the benefits of this type of feedback are that it is:

- **Corrective** so the caregiver is advised on compression or ventilation performance only when needed and can refresh their CPR skills with each use
- **Objective** in that it comes from the defibrillator, not another individual on the scene
- **Concise** to allow the caregiver to react quickly
- **Accurate** so the caregiver can 'measure' their actions for optimal ventilation and compression performance
- **Immediate** to reduce 'no flow' time (i.e., time when no CPR activity is taking place but ideally should be)
- **Prioritized based on clinical importance** so the caregiver is advised as to which aspect of their CPR performance most needs attention (e.g., compression depth over compression rate)

CPR Measurement and Feedback on a Defibrillator

Laerdal and Philips Medical Systems (Andover, Massachusetts), the world leader in cardiac resuscitation solutions, incorporated this measurement and feedback technology into a prototype HeartStart 4000SP defibrillator. A chest compression sensor (designed by Laerdal) to measure compressions and multifunction electrode pads to measure ventilations were connected to the defibrillator. The defibrillator also contained CPR quality analysis software to provide the CPR audio/visual feedback components. The HeartStart 4000SP was then used in two separate studies to determine the quality of CPR, one focused on out-of-hospital cardiac arrest and the other on in-hospital cardiac arrest. The significance of these studies, which are described as follows, is that they represent the first time objective data was collected to measure the quality of CPR (as defined by international guidelines) delivered to actual resuscitation patients.

Study 1 - Quality of Out-of-hospital CPR

In the out-of-hospital study, Wik et al.[18] examined the performance of paramedics and nurse anesthetists based on their adherence to international CPR guidelines while treating 176 patients with cardiac arrest. They determined that:

- chest compressions were given only about half (48%) of the time that the patient had no spontaneous circulation during the resuscitation events and
- only 28% of compressions given met the guideline recommendations for depth.

It is interesting to note that the paramedics and anesthetists, who had previous ACLS training with regular retraining, had all completed a refresher course immediately prior to study participation.

Study 2 - Quality of In-hospital CPR

In the in-hospital study, Abella et al.[8] measured CPR quality parameters and assessed compliance to AHA and international guidelines by well-trained BLS/ALS staff during 67 instances of cardiac arrest. It was determined that:

- compressions were administered at a low rate (<90/min.) 28% of the time,
- 37% of the compressions delivered were too shallow,
- mean proportion of time without compressions while patients were in cardiac arrest was 24%, and
- ventilation rates were higher than 20/min. just over 60% of the time.

It is worth noting that chest compressions appear to be the most important factor regarding good-quality CPR, according to both human[19] and animal studies,[20,21] and even short 4- to 5-second interruptions in compressions decrease coronary perfusion pressure.[22]

In a recent and revealing JAMA editorial,[23] Sanders and Ewy directly addressed the quality of CPR (citing several of the same studies mentioned throughout this application note) and the need to update CPR and Emergency Cardiovascular Care (ERC) guidelines, given the poor survival rates from cardiac arrest. One aspect of CPR performance they touched on was the need to change the model for training healthcare personnel and lay persons in CPR: "Perhaps only those elements that are most critical for neurologically intact survival from cardiac arrest should be taught---such as the following elements for out-of-hospital sudden cardiac collapse: push hard and push fast on the center of the chest without interruption, defibrillate promptly, and don't provide too many rescue breaths per minute."

Q-CPR™: The Measurement and Feedback Solution

To address the need to help caregivers perform high quality CPR, Philips Medical Systems and Laerdal offer the Q-CPR Measurement and Feedback tool in the Philips HeartStart MRx monitor/defibrillator. Q-CPR is the world's first and only real-time CPR measurement and feedback tool integrated into an ALS defibrillator. It provides objective measurement and real-time corrective feedback in both manual defibrillation and AED modes on compression depth and rate as well as ventilation volume and rate to encourage caregivers to perform CPR on adults (8 years of age or older or weighing more than 25 kilograms) in accordance with AHA/ERC guidelines.

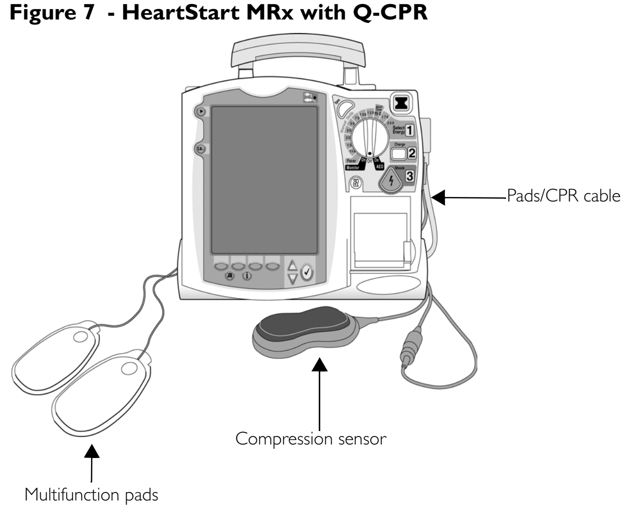
Overview

Q-CPR is easy to set up, use, and experience. It consists of:

- a pads/CPR cable,
- a lightweight (8 ounces) reusable compression sensor, and
- multifunction defibrillation electrode pads.

Figure 7 illustrates the Q-CPR configuration.

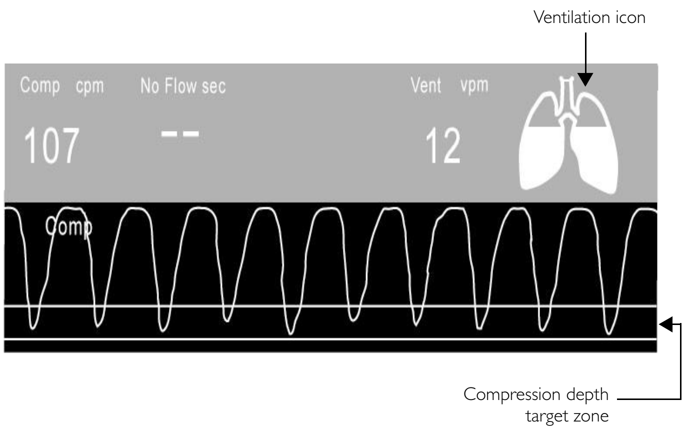
Figure 7 - HeartStart MRx with Q-CPR



Once the therapy mode is selected (i.e., manual or AED), the compression sensor is applied on the lower half of the patient's sternum, the multifunction pads are applied to the patient's chest, and ventilation is given, CPR measurement and feedback occurs automatically or manually, depending on device settings.

During use, the compression sensor measures the acceleration of the patient's chest during chest compressions and an algorithm in the HeartStart MRx converts this to compression depth. The multifunction pads measure chest impedance related to ventilation volume that is analyzed by a ventilation algorithm. An anterior/anterior pads placement is required because the algorithm interprets change in impedance based on the apex/sternum placement. The compression and ventilation algorithms produce visual measurements and related auditory/textual feedback, as appropriate, through a feedback algorithm. Figure 8 is a sample screen in manual defibrillation mode depicting the various compression and ventilation measurements.

Figure 8 - Q-CPR in Manual Defibrillation Mode: *Good CPR*



Compressions

Compression depth is presented (in Figure 8) as a waveform (labeled 'Comp') that represents about 10 seconds compressions, as derived from signals from the compression sensor. As the chest is compressed, the compression is represented as a downward stroke of the wave, rebounding up to a baseline as compression pressure is released. Two horizontal lines in the wave sector drawn at -38 mm and -51 mm (-1.5" and -2") indicate the target zone to help achieve good compression depth in accordance with AHA guidelines. A calculated compressions-per-minute (cpm) rate is displayed in the upper left corner above the wave. If compression depth or rate deviate significantly from AHA guidelines, the monitor/defibrillator provides on-screen signals and corrective audible feedback. If there is no detectable compression, a No Flow time value will count "hands off" seconds, starting at 2 seconds and incremented with each additional second.

Ventilations

The defibrillation pads collect ventilation data by detecting changes in chest impedance, which correlate to ventilation volume. The ventilation rate is presented as ventilations-per-minute (vpm) and approximate ventilation volume is indicated by the ventilation (lungs) icon. This is shown in the upper right corner above the compression wave. Like compression, if the ventilation parameters fall outside the AHA guidelines, on-screen signals and audible feedback are given.

Corrective Feedback

Audible voice prompts (in manual and AED modes) and on-screen text prompts (in AED mode only) alert the caregiver to needed adjustments in CPR performance, including lapses in compression and ventilation activity. Feedback is organized as shown in Table 2:

Table 2 - CPR feedback

Category	Performance addressed
Compression depth	Too shallow; too deep
Compression rate	Too slow; too fast
Compression duration time	Too short
Pressure on the patient's chest	Incomplete release of compression
Ventilation rate	Too low; too high
Ventilation volume	Not enough volume
Ventilation inflation time	Too slow; too fast
Compression inactivity	15, 30, 45, or 60 seconds without sign of compression
Ventilation inactivity	30 seconds without sign of ventilation
CPR inactivity (compressions or ventilations)	15, 30, 45, or 60 seconds without signs of CPR

Feedback is prioritized and delivered in the order of clinical importance. The volume of voice prompts can be adjusted or they can be muted altogether.

The following figures are two examples of feedback. Figure 9 shows manual defibrillation mode with compressions that are too shallow and would produce "Compress deeper" audio feedback. The flat compression waveform and 'No Flow' value then indicate no CPR activity for 3 seconds.

Figure 9 - Q-CPR in Manual Defibrillation Mode: ***Poor CPR***

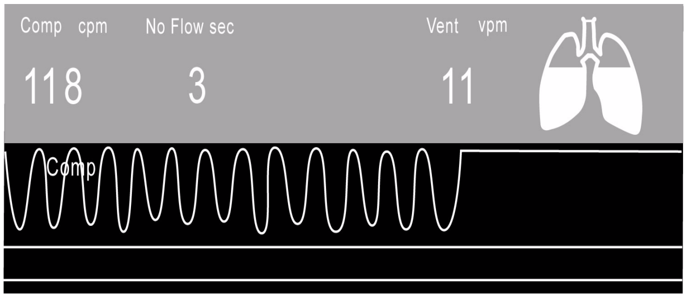
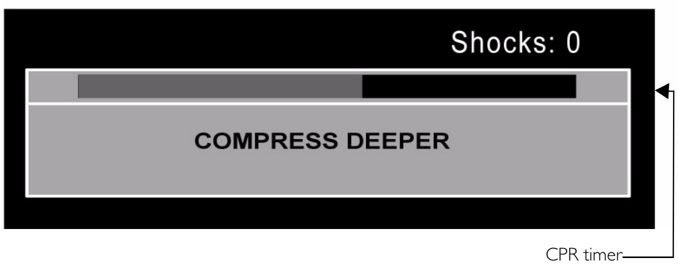


Figure 10 shows AED mode where compressions are, again, too shallow and "Compress deeper" audio and text feedback is produced. A configurable CPR Timer status bar is also displayed.

Figure 10 - Q-CPR in AED Mode: ***Poor CPR***



In both examples, once a correction is made, the related feedbacks disappear.

Additional Benefits

In addition to supporting real-time CPR performance, Q-CPR can:

- reinforce skills with each and every use.
- provide event data to demonstrate CPR guideline adherence (with optional data recording feature).
- provide event data to illustrate areas for improvement (with optional data recording feature).
- identify the most critical factors in successful CPR for future study.
- acquire CPR parameter data associated with survival for future study (with optional data recording feature).

Conclusion

Recent science provides a better understanding of the importance of CPR and how to optimize its benefits. Also, by calling attention to the current state of CPR, research encourages caregivers, advisory boards, and the medical products industry to:

- assess practices and guidelines and
- develop procedures, techniques, and tools to better address the reality of actual CPR performance.

There is no question that performing quality CPR is challenging in the real world. The environment, patient type, fatigue, and even training all affect performance. One promising advancement to help mitigate these factors is Laerdal's Q-CPR™ technology integrated into Philips' HeartStart MRx monitor/defibrillator. It is the first monitoring parameter to provide immediate, objective measurement and corrective feedback on compression and ventilation to encourage CPR performance in accordance with established guidelines.

Further research will likely bear out that this more complete understanding of CPR quality, along with advances in its delivery, will positively impact patient care. The expected refinement of guidelines and teaching practices may also contribute. All told, better patient outcome and improved survival rates should be anticipated.

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