



A Collection of Abstracts from Scientific Papers

Research Supporting Q-CPR™
Measurement and Feedback Technology



Laerdal®
helping save lives

Foreword

Please, consider the following:

- Research demonstrates that the quality of cardiopulmonary resuscitation (CPR) has a direct effect on patient outcome from cardiac arrest.
- Research also indicates caregivers, on the whole, 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 and to embrace appropriate tools and techniques to achieve that level. Q-CPR™ Measurement and Feedback Technology by Laerdal represents one such improvement option.

Our primary motivation for providing this abstract booklet is to share what we believe is significant science that points us all in a direction that can significantly improve survival from cardiac arrest. We believe that evidence and education are the motivation for change and hope that this booklet serves to be a value for you, our customers and partners.

We hope that you will find this collection of abstracts helpful in better understanding the importance of CPR quality and appropriately timed defibrillation. This booklet of abstracts is not a comprehensive review of the literature, but rather represents significant clinical works that we believe show the promise of these therapies. It is important to note that the abstracts included in this book are “our” interpretation of the literature. We have taken every effort to fairly and accurately represent the research without commercial bias. We encourage you to read the specific papers if interested.

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Quality of CPR Has an Impact on Survival

In this section we highlight some studies on both bystander and professional CPR, and the impact CPR has on survival. These papers clearly show a benefit of early initiation of quality CPR by bystanders or professionals.

Bystander CPR

- i. Bossaert and Van Hoeyweghen et al. (1989), Resuscitation, "Bystander Cardiopulmonary Resuscitation (CPR) in Out-of-Hospital Cardiac Arrest"
- ii. Van Hoeyweghen, R. J.; Bossaert L. L; Mullie, A.; Calle, P.; Martens, P.; Buylaert, W.A., Delooz, H., Belgian Cerebral Resuscitation Study Group et al. (1993), Resuscitation, "Quality and Efficiency of Bystander CPR"
- iii. Wik et al. (1994), Resuscitation, "Quality of Bystander Cardiopulmonary Resuscitation Influences Outcome after Prehospital Cardiac Arrest"
- iv. Gallagher et al. (1995), JAMA, "Effectiveness of Bystander Cardiopulmonary Resuscitation and Survival Following Out-of-Hospital Cardiac Arrest"
- v. Herlitz, J.; Svensson, L.; Holmberg, S.; Ängquist, K; Young, M. et al. (2005), Resuscitation, "Efficacy of Bystander CPR: Intervention by Lay People and by Healthcare Professionals"

Professional CPR

- i. Aufderheide et al. (2004), Circulation, "Hyperventilation-induced during Cardiopulmonary Resuscitation"
- ii. Ko et al. (2005), Resuscitation, "Evaluating the Quality of Prehospital Cardiopulmonary Resuscitation by Reviewing Automated External Defibrillator Records and Survival for Out-of-Hospital Witnessed Arrests"

Bystander Cardiopulmonary Resuscitation (CPR) in Out-of-Hospital Cardiac Arrest

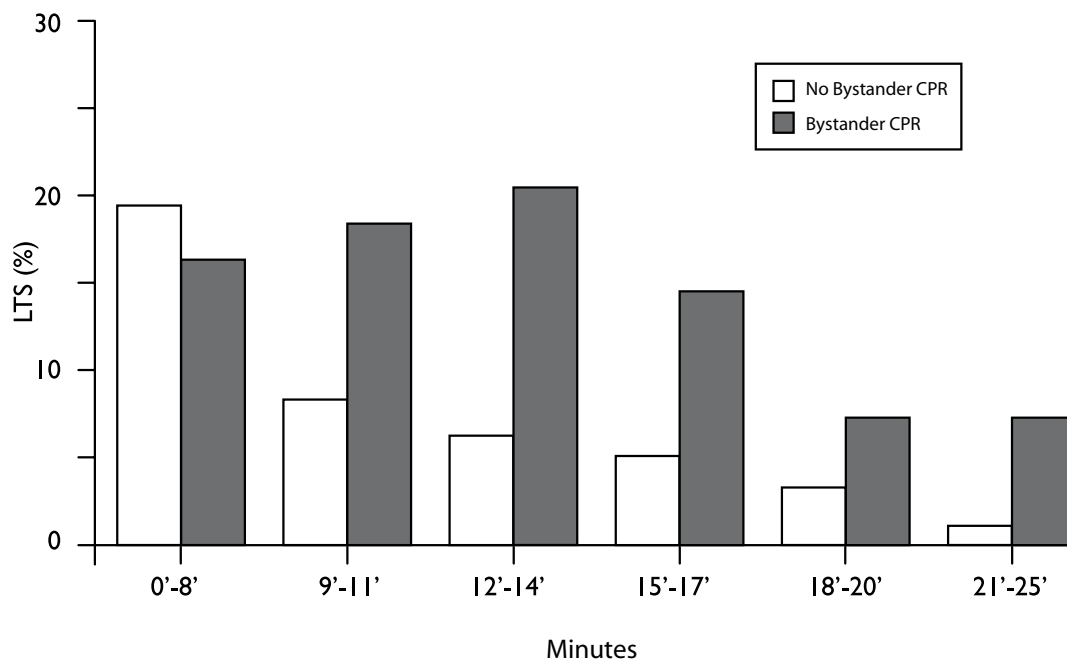
Bossaert, L., Van Hoeyweghen, R. and the Cerebral Resuscitation Study Group
Circulation, 1989, pp. 55-69

Objective: To evaluate the extent and benefit of Belgians performing out-of-hospital CPR.

Method: 3083 out-of-hospital cardiac arrest patients were analyzed. 998 patients were given bystander CPR and further studied. Mobile intensive care unit (MICU) teams performed registration of several variables of the pre-arrest, arrest, CPR and post-CPR period. The teams recorded if bystander CPR was performed, the characteristics of the bystander, the site of cardiac arrest and the quality of the CPR delivered.

Results: Out of the 998 patients that received bystander CPR, 816 patients received chest compressions and 642 patients received ventilations. Bystander CPR was performed by health care workers in 21% (19% of the chest compressions classified as bad quality), by lay people in 13% (30% of the chest compressions classified as bad quality), and by family members in only 6% (45% of the chest compressions classified as bad quality).

The percentage of long-term survival (LTS%) for patients with or without bystander CPR delivered is illustrated in the figure below. Bystander CPR did not affect LTS (%) for patients that received advanced life support (ALS) within the first 8 minutes; but, when time of ALS exceeded 8 minutes, the LTS (%) was significantly better in the bystander CPR group.



Conclusion: Bystander CPR is related to significantly improved survival rate, especially in cases with long time before ALS treatment.

Quality and Efficiency of Bystander CPR

Van Hoeyweghen, R. J.; Bossaert L. L; Mullie, A.; Calle, P; Martens, P; Buylaert, W.A., Delooz, H., Belgian Cerebral Resuscitation Study Group Resuscitation, 1993, pp. 47-52

Objective: To evaluate whether long-term survival from cardiac arrest is negatively influenced by bad quality CPR compared to no bystander CPR

Method: 3306 out-of-hospital cardiac arrests, collected during 1983-1989, were reviewed and studied. The cardiac arrests were classified as Ventricular Fibrillation (VF), asystole or electromechanical dissociation. Bystanders were categorized as lay or health care workers. 885 patients received bystander CPR. CPR was broken down and categorized as only external chest compressions (ECC), only mouth-to-mouth ventilation (MMV) or both. The quality of CPR was judged by palpation of peripheral arteries during ECC and observation of chest movement. Furthermore, the CPR technique was judged subjectively by the mobile intensive care unit teams on arrival, and was compared to the American Heart Association guidelines. Correct CPR represented good technique with good effect and/or good technique with weak effect. Incorrect CPR represented bad technique. Long term survival (LTS %) was defined as consciousness 14 days from hospital discharge. Short term survival (STS %) was defined as hospital admission, but death during the next 14 days.

Results: Patients given correct CPR had a 12% LTS and 16% STS. Patients given incorrect CPR had a 4% LTS and 12% STS. Patients given only ECC had 10% LTS and 11% STS and with only MMV the patients had 2% LTS and 22% STS. With no CPR performed the patients had a 7% LTS and a 13 % STS.

As shown in the table below, patients in VF had a LTS of 31% when correct CPR was performed, 6% LTS when performed incorrectly, 20% LTS when only given ECC, 9% when only given MMV and 15% LTS when not being given bystander CPR.

Outcome After Arrest in VF According to the Quality of CPR

Bystander CPR Performance	No ROSC (%)	STS (%)	LTS (%)	Total (n)
Correct	52	18	31	188
Incorrect	71	21	8	38
Only ECC	68	12	20	113
Only MMV	45	45	9	11
No Bystander CPR Performed	61	24	15	615

Conclusion: Bystander CPR is related to significantly improved survival rate and might have the beneficial effect of maintaining the heart in VF by ECC. A significant negative effect on survival was not found comparing incorrect CPR and no bystander CPR.

Quality of Bystander Cardiopulmonary Resuscitation Influences Outcome After Prehospital Cardiac Arrest

Wik, L, MD, PhD; Steen, P.A.; Bircher, N.G.
Resuscitation, 1994, pp. 195-203

Objective: To evaluate the effect of quality bystander CPR on hospital discharge rates for patients after out-of-hospital cardiac arrests.

Methods: CPR was categorized as “good” if the carotid or femoral pulse was palpable and intermittent chest expansion was observed with ventilations. Otherwise, CPR was recorded as “bad” or “no bystander CPR”.

The outcome by quality of bystander CPR is shown in the table below. The results are given as the ratio of the number of patients discharged from hospital divided by total number of patients.

Survival Outcome by Quality of Bystander CPR

Bystander CPR	At Home	In Public	Total
Good	5/31	11/39	16/70
Bad	0/32	1/47	1/79
No Bystander CPR	6/121	5/64	11/185
Total	11/184	17/150	28/334

Results: The results show a hospital discharge rate of 23% with good bystander CPR compared with a 1% discharge rate with bad bystander CPR ($p < 0.0005$), and a 6% discharge rate with no bystander CPR.

Conclusion: Good bystander CPR was associated with a much higher discharge rate from hospital after prehospital cardiac arrest among the 334 patients. Wik et al. conclude that: “...educational efforts directed at bystander CPR performance that meets two simple criteria; (1) palpable pulse with chest compression and (2) chest expansion with ventilation, may improve outcome in prehospital cardiac arrest.”

Effectiveness of Bystander Cardiopulmonary Resuscitation and Survival Following Out-of-Hospital Cardiac Arrest

Gallagher, J.E.; Lombardi, G., MD; Gennis P., MD,
JAMA, 1995, Vol. 274, No. 24, pp. 1922-1925

Objective: To examine the nature and extent of the independent relationship between quality of bystander CPR and survival following out-of-hospital cardiac arrest.

Methods: 2071 cardiac arrest patients were included and classified as receiving bystander CPR if bystanders at the scene were attempting sternal compressions or rescue breathing. The criteria for effective CPR were twofold: (1) ventilations had to produce a visible expansion of the chest wall and (2) a carotid or femoral pulse had to be palpable during chest compressions. The assessment of CPR quality was done by professional Emergency Medical Technicians (EMTs). The EMTs had a current American Heart Association (AHA) certification in basic life support and a minimum of 4 years experience.

Results: Of the total 2071 cardiac arrest patients included in the study only 1.4% survived. 662 patients received bystander CPR. These patients had a survival rate of 2.9%. The patients that did not receive bystander CPR had a survival rate of 0.8%. Of the 662 patients receiving bystander CPR, only 46% had it performed effectively (according to the above stated criteria). 4.6% of the patients who received effective CPR survived versus 1.4% survival with ineffective CPR, representing more than three-fold improvement or an Odds Ratio (OR) = 3.4. After adjusting for other factors such as interval from collapse to CPR, effective CPR remained independently associated with improved survival (OR = 3.9).

Conclusion: Effective bystander CPR is independently associated with quantitatively and statistically significant improvement in survival outcome following out-of-hospital cardiac arrest.

Efficacy of Bystander CPR: Intervention by Lay People and by Healthcare Professionals

Herlitz, J.; Svensson, L.; Holmberg, S.; Ångquist, K.; Young, M.
Resuscitation, 2005, pp. 291-295

Objective: To evaluate the impact on survival of no bystander CPR, lay bystander CPR and professional bystander CPR. The study is a follow up to the year 2000 study with a detailed description of the patient outcome considering whether the bystander was a lay person or a professional.

Method: The study is based on the Swedish Cardiac Arrest Registry and covers the period 1990-2002. A total of 29711 patients with out-of-hospital cardiac arrest who were given CPR and were not witnessed by the ambulance crew were included and studied.

Results: 36 % of the patients received bystander CPR. Of these, 72% was initiated by lay persons and 28% by professionals. As shown in the table below patients who received CPR from lay persons were hospitalized alive more frequently than patients that did not receive bystander CPR. Moreover, patients who received bystander CPR from professionals were hospitalized alive more frequently than the patients who received lay person bystander CPR.

Characteristics and Result in Relation to Type of Bystander Among All Patients

Bystander CPR Performance	No B-CPR	Lay Person CPR	Professional CPR
Bystander Witnessed	58	73	78
Place: At Home	72	60	32
Initial Rhythm	27	38	44
Interval Between: Call for and Arrival of EMS (Median; min.)	6	8	6
Hospitalized Alive	12.8	16.1	22.9
Alive at 1 Month	2.2	4.9	9.2

A multivariate analysis (adjusting for dissimilarities in age, sex, place of arrest, witnessed status and emergency medical service response time) was performed and showed that lay bystander CPR was associated with improved survival compared to no bystander CPR with an odds ratio (OR) of 2.04. In the same multivariate analysis, professional bystander CPR was associated with improved survival compared to lay bystander CPR with an OR of 1.37.

For the bystander witnessed cardiac arrest patients (n=17050) the survival rate at 1 month after arrest was 3.1% for the no-bystander CPR group, 6.2% for the lay bystander CPR group and 10.8% for the professional CPR group. When performing the same multivariate analysis (as in the above paragraph), more patients were alive month after cardiac arrest (OR=2.16) when they received bystander CPR from lay persons versus no bystander. Furthermore, the multivariate analysis showed that patients who received bystander CPR from professionals versus lay persons had a increased survival with an OR of 1.31.

Conclusion: Bystander CPR performed by lay persons is associated with an two-fold increase in the chance of survival from out-of-hospital cardiac arrest (in a multivariate analysis). Furthermore, when bystander CPR is performed by healthcare professional the survival rate is even higher. However, the authors note in their conclusion that these differences may not be explained by differences in the quality of CPR.

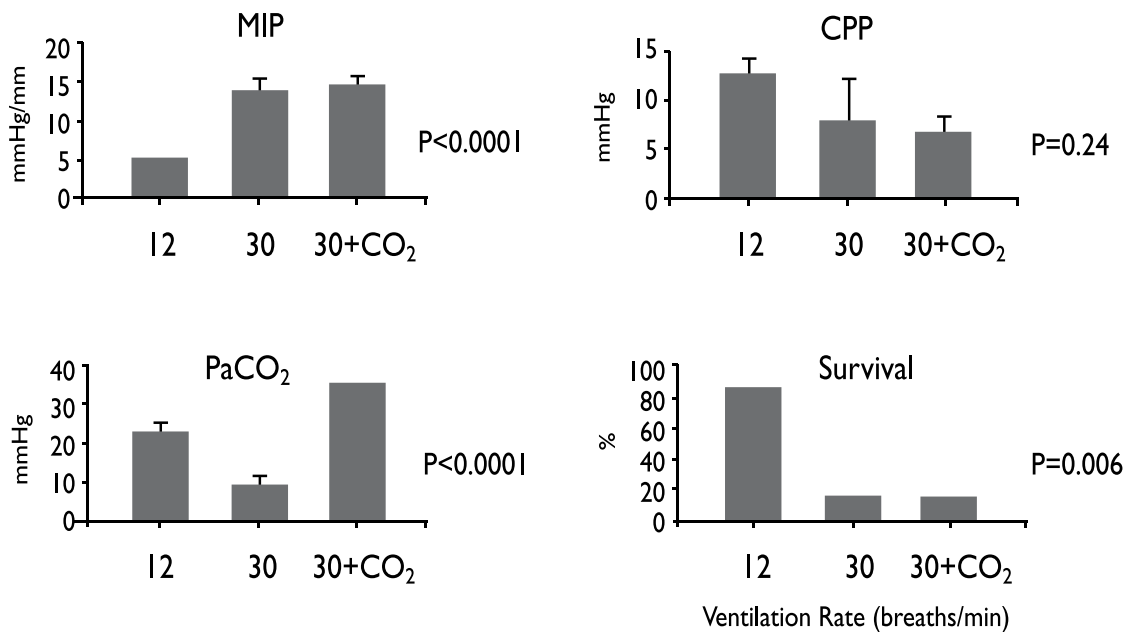
Hyperventilation-induced Hypotension During Cardiopulmonary Resuscitation

Aufderheide, T.P., MD; Sigurdsson, G., MD; Pirrallo, R.G., MD, MHSA; Yannopoulos, D. MD; McKnite, S., BA; Von Briesen, BA, EMT; Sparks, C.W., EMT; Conrad, C.J., RN; Provo, T.A., BA, EMT-P; Lurie K.G., MD
Circulation, 2004, 109, pp. 1-6

Objective: To quantify the degree of excessive ventilation rates during CPR and determine the effect on Coronary Perfusion Pressure (CPP) and survival.

Methods: Excessive ventilation rates on humans performed by professional rescuers were quantified. Thereafter, the researchers performed the same excessive ventilations on pigs to determine the effect of significantly reduced CPP and survival.

Results: 6 out of 7 pigs ventilated at 12 breaths per minute survived (bottom right graph). Pigs ventilated with 30 breaths per minute, with or without an added 5% of CO₂, had a survival rate of 1 out of 7.



Survival study with 7 pigs per group. Changes in mean intrathoracic pressure (MIP), arterial CO₂ (PaCO₂), coronary perfusion pressure (CPP), and Survival rate, with hyperventilation and correction of hypocapnia (+CO₂).

Conclusion: Mean Intrathoracic Pressure (MIP) was significantly higher with higher Ventilation Rates (VR), and CPP was lower. This suggests that hyperventilation significantly increases MIP, reduces CPP to right heart and has a negative impact on survival from cardiac arrest.

Evaluating the Quality of Prehospital Cardiopulmonary Resuscitation by Reviewing Automated External Defibrillator Records and Survival for Out-of-Hospital Witnessed Arrests

Ko, P.C.; Chen, W.; Lin, C., MA, M.H., Lin, F.
Resuscitation, 2005, 64: pp. 163-169

Objective: To evaluate the quality of prehospital CPR performance and its impact on outcome in witnessed ventricular fibrillation (VF) patients using electrocardiography (ECG) and voice data in Automated External Defibrillators (AEDs). It is the first study to evaluate the quality of prehospital CPR using AED data for patients in need of post-shock CPR.

Methods: A retrospective analysis of AED data collected and stored in the ForeRunner AED (Philips Medical Systems). ECG and voice records were reviewed for 633 out-of-hospital arrests. Software (CodeRunner) was used for the rhythm review and annotation of times from dispatch and sound records. Only witnessed VF arrests, without Return of Spontaneous Circulation (ROSC) immediately after defibrillation requiring post-shock CPR, were included in the study. Therefore, 52 witnessed cardiac arrests in VF underwent an independent structured review.

Quality of CPR in the prehospital setting was categorized as either adequate or inadequate. Adequate quality of CPR met four criteria: (1) noticeable deflection of ECG upon chest compressions, supplemented by audible verbal counting; (2) more than 50 chest compressions per minute delivered; (3) after the AED prompt “if no pulse, start CPR” CPR was resumed and continued until ROSC, or for no less than 3 minutes on the scene, before transport. Those without ROSC within 3 minutes should have CPR continued with no more than 30 seconds interruption during transport; (4) for refractory VF patients after 3 sequential shocks, CPR should be resumed for 1 minute before next shock is advised.

Results: The quality of prehospital CPR was categorized as inadequate for 37 out of the 52 witnessed out-of-hospital cardiac arrests. The table below shows that patients that received adequate CPR had higher rates of ROSC on Scene (53% versus 8%), higher ROSC in Hospital (87% versus 14%), higher Survival to Admission (73% versus 8%), and higher Survival to Discharge (53% versus 8%).

Quality of Prehospital CPR vs. Outcomes

	Adequate CPR (N=15)	Inadequate CPR (N=37)
ROSC on Scene	8/15 (53%)	3/37 (8%)
ROSC in Hospital	13/15 (87%)	5/37 (14%)
Survival to Admission	11/15 (73%)	3/37 (8%)
Survival to Discharge	8/15 (53%)	3/37 (8%)

Conclusion: Survival to hospital discharge was more than six times higher for patients that received adequate CPR versus the patients receiving inadequate CPR.



CPR Before First Shock Can Improve Survival

Wisdom from the late 80's and 90's pointed us in the direction of AEDs suggesting that they were the “silver bullet” for survival from Sudden Cardiac Arrest (SCA). Despite tremendous deployment of AEDs throughout this period of time, limited benefit in terms of survival was seen in traditional EMS settings. The papers in this section provide a clearer understanding of how quality CPR and early defibrillation work better “together” to improve chances of survival from SCA in our communities.

- i. Cobb et al. (1999), JAMA, “Influence of Cardiopulmonary Resuscitation Prior to Defibrillation in Patients with Out-of-Hospital Ventricular Fibrillation”
- ii. Weisfeldt et al. (2002), JAMA, “Resuscitation after Cardiac Arrest – A 3-phase Time-Sensitive Model”
- iii. Wik et al. (2003), JAMA, “Delaying Defibrillation to give Basic Cardiopulmonary Resuscitation to Patients With Out-of-Hospital Ventricular Fibrillation – A Randomized Trial”
- iv. Vilke et al. (2005), Resuscitation, “The Three-phased Model of Cardiac Arrest as Applied to Ventricular Fibrillation in a Large, Urban Emergency Medical Service System”

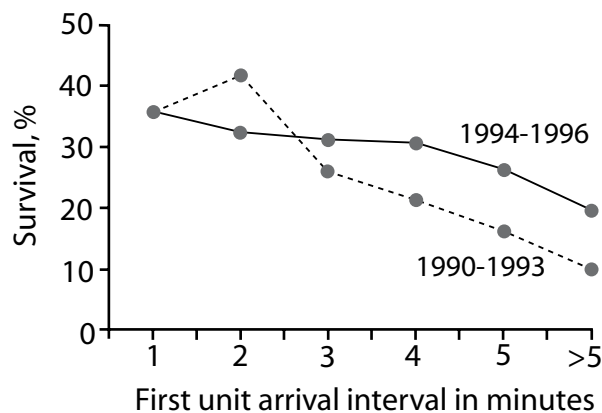
Influence of Cardiopulmonary Resuscitation Prior to Defibrillation in Patients With Out-of-Hospital Ventricular Fibrillation

Cobb, L.A., MD; Fahrenbruch, C.E., MSPH; Walsh, T.R., NREMT-P; Copass, M.K., MD; Olsufka, M., RN; Breskin, M., MS; Hallstrom, A.P., PhD
JAMA, 1999, Vol. 281, No. 13, pp. 1182-1188

Objective: To evaluate the effects of first responding Emergency Medical Technicians (EMTs) providing 90 seconds of CPR to individuals with out-of-hospital ventricular fibrillation before the delivery of a shock.

Background and Methods: Since 1970, the outcomes of all patients treated for cardiac arrest in Seattle have been monitored. Data show that when AEDs were introduced and given the highest importance in the treatment of out-of-hospital cardiac arrests, the survival rates decreased. During 1990-93, a total of 639 patients were treated for out-of-hospital VF without 90 seconds of CPR before shock. In 1994 the protocol changed; 90 seconds of CPR was performed prior to the delivery of a shock. From 1994-96, 478 patients were treated with 90 seconds of CPR prior to shock.

Results: The Figure illustrates that survival improved when (during 1994-96) patients were given 90 seconds of CPR before shock (compared to no CPR during 1990-93). That is, the overall survival rate to hospital discharge went from 24% to 30%. The increase in the survival rate was predominantly with patients who had an initial response time greater than 4 minutes.



1990-1993 (n=639), No.	22	91	205	164	86	71
1994-1996 (n=478), No.	14	80	164	114	65	41

Conclusion: The overall survival rate to hospital discharge from out-of-hospital cardiac arrest improved from 24% to 30% when 90 seconds of CPR was performed compared to no CPR before shock.

Resuscitation After Cardiac Arrest – A Three-Phase Time Sensitive Model

Weisfeldt, M.L., MD and Becker, L.B., MD,
JAMA, 2002, Vol. 288, No. 23, pp. 3035-3038

Objective: To propose a three-phase model of resuscitation of CPR. The model reflects the time-sensitive progression of resuscitation physiology. It is advocated that optimal treatment of cardiac arrest is phase-specific. More specifically:

1. **The electrical phase:** That is, from time of cardiac arrest until approximately 4 minutes after cardiac arrest.

As an example of the efficacy of defibrillation during the electrical phase, Weisfeldt et al. 2002 point to the success of the implantable cardioverter defibrillator. This apparatus provides defibrillation within 15 to 20 seconds after the start of VF and seldom fails to restore normal heart rhythm. The effectiveness of early defibrillation is well established and can collectively result in 50% survival rates.

2. **The circulatory phase:** That is, from approximately 4 minutes until 10 minutes after cardiac arrest.

Weisfeldt et al. list numerous studies, animal and clinical human studies, which support initiating CPR before defibrillation in the circulatory phase (among the listed studies are Cobb et al. 1999 and Wik et al. 2003 summarized here). Optimal implementation of this change in therapy is complex and would require a method or device to verify time since collapse. However, if this change in therapy were to be implemented, it could affect a large number of cardiac arrest cases because most victims are treated during the circulatory phase.

3. **The metabolic phase:** That is, from 10 minutes after cardiac arrest and beyond.

In the metabolic time frame immediate defibrillation and CPR have significantly decreased effectiveness and survival rates are poor. According to the authors, it is unknown whether therapeutic approaches have an effect on irreversible injury occur during this phase.

A limitation of the three-phase model is that it only addresses the physiology Ventricular Fibrillation (VF)-mediated cardiac arrest. Little data is available to suggest how the model would be applied to pulseless electrical activity (PEA) or asystolic arrest. Nevertheless, the benefits of applying the three-phase model to VF cardiac arrest victims have strong support from other studies and may significantly increase survival rates to hospital discharge from VF cardiac arrests.

Delaying Defibrillation to Give Basic Cardiopulmonary Resuscitation to Patients With Out-of-Hospital Ventricular Fibrillation – A Randomized Trial

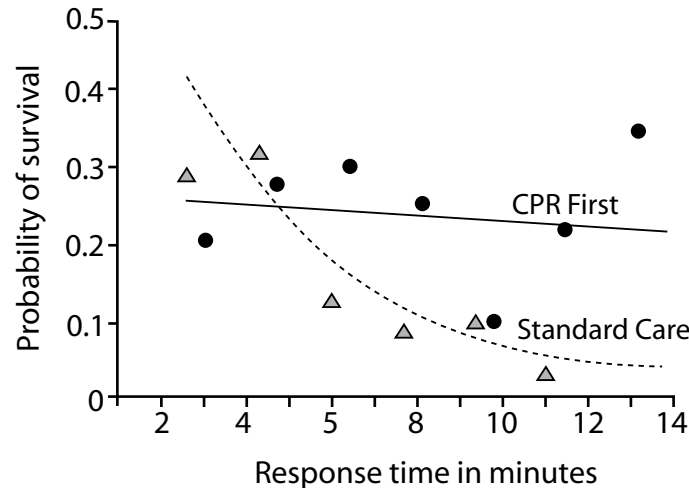
Wik, L., MD, PhD; Hansen, T.B.; Fylling, F.; Steen, T., MD; Vaagenes, P., MD, PhD; Auestad, B.H., PhD; Steen, P.A., MD, PhD
JAMA, March 19, 2003, Vol. 289, No. 11

Objective: To examine the effects of delaying defibrillation to give basic CPR to patients with response times either up to or longer than 5 minutes.

Methods: A randomized trial of 200 patients with out-of-hospital VF was studied. The “Standard Care” group was given defibrillation immediately upon ambulance personnel arrival. If Return of Spontaneous Circulation (ROSC) was not achieved after 2 shocks, 1 minute of CPR was performed on VF patients. 3 minutes of CPR was performed on non-VF cardiac arrest patients.

The “CPR First” group was given the same treatment, though with the important exception of 3 minutes of CPR prior to the first shock. If the first shock was unsuccessful, another 3 minutes of CPR was performed.

Results: The figure illustrates the estimated probabilities of survival to hospital discharge plotted against the response times. In the “Standard Care” group (shock first) 15% of 96 patients survived versus 22% of 104 patients in the “CPR First” group. For patients with ambulance response times less than 5 minutes, there were no differences in the outcome variables between the two groups. However, with ambulance response times greater than 5 minutes, 58% of the “CPR First” group received Return of Spontaneous Circulation (ROSC) versus 38% in the “Standard Care” group.



Average fraction of surviving patients for each 2-minute interval.
Lines indicate logistic regression models with time as an independent variable fitted separately for each of the two groups.

Conclusion: For Emergency Medical Technician (EMT) response times greater than 5 minutes, the delivery of CPR before defibrillation significantly increases the rate of survival.

The Three-Phase Model of Cardiac Arrest as Applied to Ventricular Fibrillation in a Large, Urban Emergency Medical Services System

Vilke, G.M.; Chan, T.C.; Dunford, J.V.; Metz, M.; Ochs, G.; Smith, A.; Fisher, R.; Poste, J.C.; McCallum-Brown, L.; Davis, D.P.
Resuscitation, 2005, No. 64, pp. 341-346

Objective: To study the relationship between time since cardiac arrest collapse, and performance of bystander CPR and survival.

Methods: Data records for 1,141 non-traumatic cardiac arrest victims were studied.

Results: The table presents the percentage survival of cardiac arrest victims with and without performance of bystander CPR prior to EMS arrival.

Percentage Survival With and Without Bystander CPR

Time since collapse	Number of Patients	Survival (%)	
		CPR	No CPR
Less than 4 minutes	18	40.0	38.5
4 minutes or greater	254	17.3	0
4-10 minutes	46	26.7	0
Greater than 10 minutes	37	0	0
Unknown	171	18.9	0

With no bystander CPR delivered, no patients survived when time since collapse exceeded 4 minutes. The survival rate was 26.7% for patients receiving bystander CPR within 4-10 minutes. Patients in the “unknown” category all had response times greater than 4 minutes. Hence, these data were included in the “4 minutes or greater” category. No patients with time since collapse greater than 10 minutes survived.

Conclusion: For patients with time since cardiac arrest of more than 4 minutes, the performance of bystander CPR, prior to EMS arrival, increased the chance of successful resuscitation and long-term survival. For patients with time since cardiac arrest less than 4 minutes there was no survival advantage to bystander CPR versus no CPR.



Quality of CPR by Healthcare Professionals

Some landmark papers were published during 2005 that give us new insight on the quality of CPR performed by healthcare professionals (when compared to published guidelines). In summary, compliance to guidelines suffers in many areas, which is likely to be detrimental to survival. Some of the factors that contribute to this are current protocols, challenging environments for performance of CPR and no objective way to monitor the quality being provided. These papers identify CPR quality as a broad system issue rather than an individual rescuer problem, and draw attention to the need for improved focus on the quality of basic CPR that is provided by emergency care personnel.

- i. Abella et al. (2005), JAMA, "Quality of Cardiopulmonary Resuscitation During In-Hospital Cardiac Arrest"
- ii. Abella et al. (2005), Circulation, "Chest Compressions Rates During Cardiopulmonary Resuscitation are Suboptimal – A Prospective Study During In-hospital Cardiac Arrest"
- iii. Wik et al. (2005), JAMA, "Quality of Cardiopulmonary Resuscitation During Out-of-Hospital Cardiac Arrest"

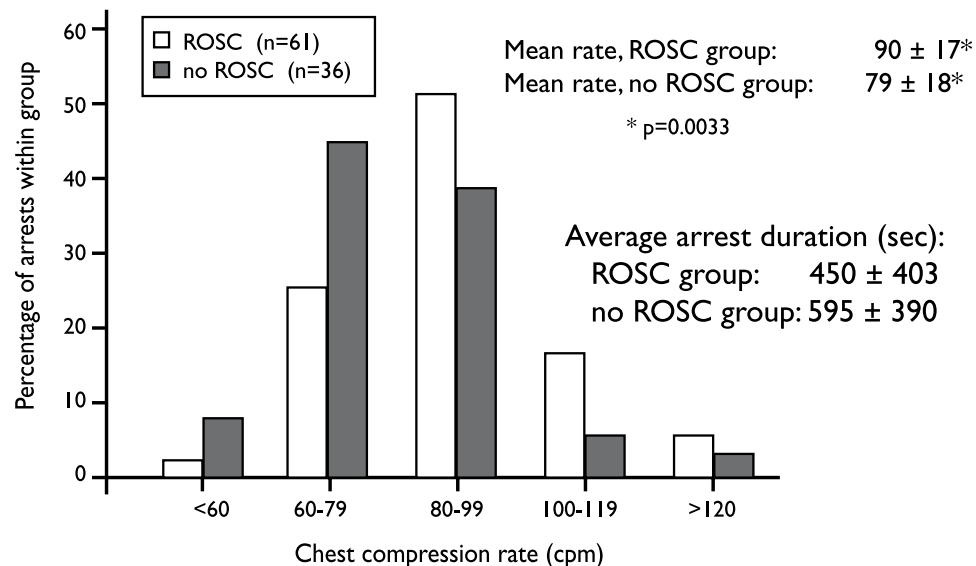
Chest Compression Rates During Cardiopulmonary Resuscitation are Suboptimal – A Prospective Study During In-Hospital Cardiac Arrest

Abella, B.S., MD, MPhil; Sandbo, N., MD; Vassilatos, P., MS; Alvarado, J.P., BA; O'Hearn, N., RN, MSN; Wigder H.N., MD; Hoffman, P., CRT; Tynus, K., MD; Hoek, T.L.V., MD; Becker L.B., MD
Circulation, 2005, 111: pp. 428-434

Objective: To measure in-hospital chest compression rates and the adherence to international CPR guidelines among trained healthcare professionals.

Methods: The study included 97 cardiac arrests. CPR was performed by nurses, resident physicians and medical students. At a minimum, all were certified in Basic Life Support (BLS). A Personal Digital Assistant (PDA) was used to record real-time chest compression rates. The investigators pressed a button on the PDA in a synchronized 1-to-1 fashion with each compression delivered. This method of data collection was tested and validated as reliable using a videotape where chest compressions were delivered and rate known. For each patient, average chest compression rates were calculated for each 30 second segment.

Results: The compression rates were less than 80 per minute in 37% of the total 30 second segments, and less than 70 per minute for 22% of the 30 second segments. Chest compressions were at 100 ± 10 (American Heart Association recommended) per minute in only 31% of the segments.



Patients that attained Return of Spontaneous Circulation (ROSC) were given higher chest compression rates. The mean compression rate for initial survivors (ROSC group) was 90 ± 17 compressions per minute (cpm). Non-survivors (no ROSC) had 79 ± 18 cpm delivered.

With respect to chest compression rates, the bottom quartile had a significantly reduced likelihood of survival (42% achieved ROSC). 1st and 2nd upper quartiles had similar ROSC rates (75% and 76%, respectively) implying that survival may be diminished only if the compressions fall below a certain critical value.

Conclusion: In-hospital chest compression rates were significantly below recommended international CPR guidelines. The suboptimal number of chest compressions per minute correlates to poor ROSC and survival.

Quality of Cardiopulmonary Resuscitation During In-Hospital Cardiac Arrest

Abella, B.S., MD, MPhil; Alvarado, J.P., BA; Myklebust, H., BEng; Edelson, D.P., MD; Barry, A., RN, MBA; O'Hearn, N., RN, MSN; Hoek, T.L.V., MD; Becker, L.B., MD
JAMA, January 19, 2005, Vol. 293, No. 3, pp. 305- 310

Objective: To measure in-hospital CPR quality, given the proven survival benefit of high-quality CPR and that little objective data on actual performance exists.

Methods: The study was purely observational, and included 67 patients, who had experienced in-hospital cardiac arrest. An investigational monitor/defibrillator (HeartStart 4000SP, Philips Medical Systems) was used to collect and measure depth and rate of chest compressions, ventilations, pulse, electrocardiogram and defibrillator shock event data. A customized software for data analysis collected these parameters and calculated the no-flow time and the fraction of cardiac arrest time without compressions. Chest compressions were measured via a special chest compression pad equipped with an accelerometer and pressure sensor. Ventilation and pulse data were measured using impedance measurements derived from the defibrillation pads.

Results: The analysis of the first 5 minutes of each resuscitation, analyzed by 30-second segments, disclosed chest compression rates less than 90 per minute in 28% of the segments. Furthermore, 37% of the delivered compressions were too shallow. 61% of the ventilations were higher than 20 per minute, thus too high compared to recommended international CPR guidelines.

Conclusion: The results from the study revealed very poor CPR quality in the in-hospital setting. That is, too few and shallow chest compressions, and too many ventilations per minute.

Quality of Cardiopulmonary Resuscitation During Out-of-Hospital Cardiac Arrest

Wik, L., MD, PhD; Kramer-Johansen, J., MD; Myklebust, H., BEng,
JAMA, 2005, Vol. 293, No. 3, pp. 299-304

Objective: To assess adherence to international CPR guidelines.

Methods: The study included a case series of 176 out-of-hospital cardiac arrest patients who were treated by nurses and paramedics in Akershus, Norway, Stockholm, Sweden and London, England. The researchers deployed HeartStart 4000 (Philips Medical Systems) prototypes in 6 ambulances in each of the 3 regions. The defibrillator had a sternal pad fitted with an accelerometer that measured and recorded chest compressions. Ventilations were measured by changes in thoracic impedance between the defibrillator pads.

Results: Over the entire episode of CPR, chest compressions were not given 48% of the time. When adjusted for the (necessary) electrocardiographic analysis and defibrillation, this number was 38%. Only 28% of the compressions adhered to international guidelines for CPR (between 38-51mm with complete release).

Performance of CPR During the First Five Minutes and Entire Episode of CPR*

	First Five Minutes of CPR	Entire Episode of CPR
No flow (n=176)		
NFR, %	49 (21)	48 (18)
NFR.adj., %	42 (19)	38 (17)
Compression (n=176) Compressions/minute	60 (25)	64 (23)
Compression rate/minute	120 (20)	121 (18)
Depth per episode, mm	35 (10)	34 (9)
38-51 mm w- /complete release	27 (30)	28 (25)
Too deep (>51mm)	0 (0-3)	0 (0-5)
Too shallow (<38 mm)	59 (37)	62 (33)
Incomplete release, %	0 (0-1)	0 (0-2)
Duty cycle, %	41 (5)	42 (4)
Ventilations/minute (n=163)	8 (4.6)	11 (4.7)

Abbreviations: NFR %, no flow ratio, the time without CPR as a percentage of the time without spontaneous circulation; NFR.adj, no flow ratio, adjusted by subtracting time allowed for electrocardiography analysis, possible defibrillation, and required pulse checks in the numerator.

*All data are expressed as mean (SD) unless otherwise noted.

Conclusion: Over the entire episode of CPR, there were no chest compressions delivered nearly half of the time. When delivered, just around one third adhered to recommended CPR guidelines.



Quality of CPR Can Be Improved by Less Hands-off Time

In addition to the quality of compressions and ventilations being suboptimal during CPR, there is also far too much time when no compression activity is taking place. The articles in this section speak to the problems caused by inadequate perfusion of the patient during cardiac arrest, and highlight the need for much greater attention by rescuers on maintaining compression activity throughout the resuscitation attempt.

- i. Eftestoel et al. (2002), *Circulation*, "Effects of Interrupting Precordial Compressions on the Calculated Probability of Defibrillation Success During Out-of-Hospital Cardiac Arrest"
- ii. Steen et al. (2003), *Resuscitation*, "The Critical Importance of Minimal Delay Between Chest Compressions and Subsequent Defibrillation: A Haemodynamic Explanation"
- iii. Van Alem et al. (2003), *Annals of Emergency Medicine*, "Interruption of Cardiopulmonary Resuscitation with the Use of the Automated External Defibrillator in Out-of-Hospital Cardiac Arrest"
- iv. Rea et al. (2005), *Annals of Emergency Medicine*, "Automated External Defibrillator: To What Extent Does the Algorithm Delay CPR"
- v. Venezuela et al. (2005), *Circulation*, "Interruptions of Chest Compressions During Emergency Medical Systems Resuscitation"

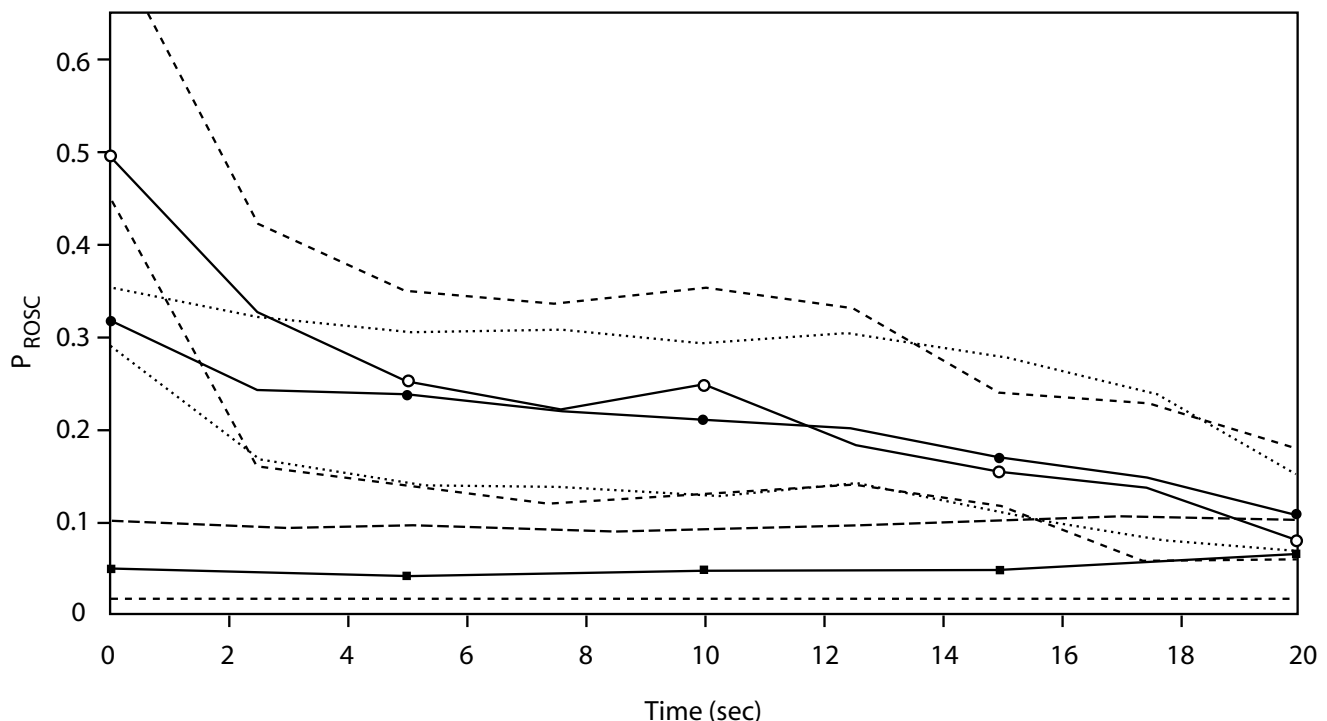
Effects of Interrupting Precordial Compressions on the Calculated Probability of Defibrillation Success During Out-of-Hospital Cardiac Arrest

Eftesdoel, T., PhD; Sunde, K., MD, PhD; Steen, P.A., MD, PhD
Circulation, 2002, Vol. 105, pp. 2270-2273

Objective: To evaluate whether the probability for Return of Spontaneous Circulation (ROSC) is reduced during the hands-off interval for patients with VF cardiac arrest.

Methods: The study was observational with data collected from the HeartStart 3000 defibrillator. A factor indicating the probability of achieving ROSC, (pROSC), was developed based on Ventricular Fibrillation (VF) signal characteristics from 868 defibrillation attempts in 156 patients. Possible changes in the ECG during hands-off intervals were studied. The median of the hands-off interval was 20 seconds. The intervals were divided according to the initial value of pROSC at the start of the hands-off intervals; low (0.00-0.25), medium (0.25-0.40) and high (0.40-1.00). pROSC was updated every 0.25 seconds, hence time series were computed that reflected the changes in pROSC for every interval. The median value for pROSC and 25th and 75th percentiles were calculated for each time instant to represent the average pROSC and its uncertainty.

Results: The ECG study indicated that the probability of achieving ROSC with defibrillation decreased during periods with no chest compression for patients starting with a high-to-medium chance of success. As illustrated in the figure, the hands-off intervals with a high pROSC declined rapidly during the first seconds to the medium level. The medium and low level of pROSC did not deteriorate as fast.



Conclusion: During resuscitation from VF, the interval between the discontinuation of chest compression and defibrillation should be as small as possible.

The Critical Importance of Minimal Delay Between Chest Compressions and Subsequent Defibrillation: A Haemodynamic Explanation

Steen, S.; Liao, Q.; Pierre, L.; Paskevicius, A., Sjöberg, T.
Resuscitation, 2003, Vol. 58, pp. 249-258

Objective: To explain; (1) why it is difficult to achieve Return of Spontaneous Circulation (ROSC) after more than 4 minutes of VF cardiac arrest; (2) why it is important to give chest compressions before defibrillation in situations with more than 4 minutes of VF; (3) the pathological changes that occur that negatively affect ROSC when chest compressions are interrupted prior to defibrillation.

Methods: 24 pigs were randomized into 3 groups of 6 pigs in each. VF was induced in the air-ventilated pigs, and then the air was withdrawn. The 3 groups of pigs had VF ongoing for 6,5 minutes, after, ventilation with 100% oxygen was started in all pigs. The 3 groups were then treated as follows: Group 1: defibrillation was attempted. Three shocks were given at 20 seconds interval. Group 2: Mechanical compression-decompression (mCPR) was given for 3,5 minutes followed by 40 seconds of hands-off before defibrillation. If unsuccessful defibrillation, mCPR started again for 30 additional seconds prior to a second or third, 40 second delayed, shock was delivered. Group 3: mCRR was given for 3,5 minutes. Then, ongoing mCPR was given while, if needed, 3 shocks were delivered.

Results and Discussion: No pigs achieved ROSC in group 1, 1 out of 6 in group 2, and 5 out of 6 in group 3. In group 3, 4 out of 6 pigs achieved ROSC after the first defibrillation attempt.

During acute VF, blood is pooled in the venous circulation. Thus, over approximately 3 minutes, the right heart becomes increasingly distended and the left heart increasingly drained. After approximately 5 minutes, when the blood pressure on the arterial side of the heart equals the venous side, the coronary perfusion pressure (CPP) and the carotid flow reduce to zero. As chest compressions are started, carotid artery increases to adequate levels within 10 seconds, but it takes 1 minute to get CPP (which now has dropped to negative values) back to zero. A further 30 seconds are necessary to get CPP to an adequate level. Hence in the treatment of prolonged VF, it appears to be important to give chest compressions before defibrillation in order to have the physiological requisites for ROSC.

Conclusion: VF caused venous congestion, the right heart to become increasingly distended and the left heart progressively drained within 3 minutes. The results indicate that the probability of achieving ROSC was greater with adequate chest compressions before and during defibrillation.

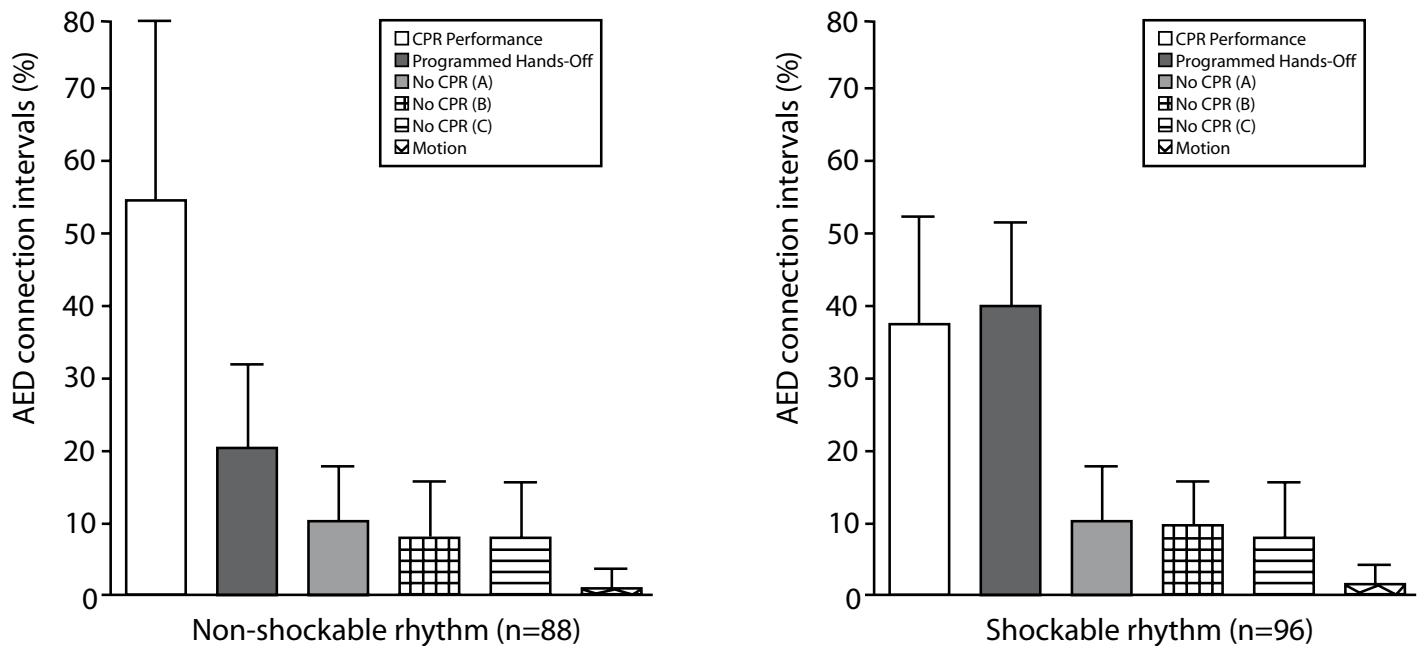
Interruption of Cardiopulmonary Resuscitation With the Use of the Automated External Defibrillator in Out-of-Hospital Cardiac Arrest

Van Alem, A.P., MD; Sanou, B.T., MSc; Koster, R.W., MD, PhD
Annals of Emergency Medicine, 2003, 42:4, pp. 449-457

Objective: To evaluate the actual interruption time of CPR from using Automated External Defibrillators (AEDs) with voice prompts on patients in out-of-hospital cardiac arrest.

Methods: 184 patients were studied. Lifepak 500 AEDs (Medtronic Physio-Control) were applied by first responders (police and fire brigades). The data collection included Electrocardiogram (ECG) and sound recordings from the AEDs, which were downloaded to computer software and analyzed. The total time of CPR with AED was also analyzed.

Results: The AEDs were connected for an average time of 4 minutes and 47 seconds. The figure below illustrates the distribution of the performance of CPR, and the AED programmed and performance-related interruption of CPR.



In patients with nonshockable initial rhythm, CPR was absent 46% of the time the AED was connected as a result of programmed instructions and CPR performance of the first responders. In patients with shockable rhythm, CPR was absent 63% of the time as a result of the same reasons. For the shockable rhythm group, the programmed hands-off interval made up 40% of the total AED connection time. Furthermore, no CPR was performed, with respect to first responder performance, during 23% of the time.

Conclusion: First responders using AED voice prompts provided CPR to the patients less than half the time the AED was connected to the patient.

Automated External Defibrillator: To What Extent Does the Algorithm Delay CPR

Rea, T.D., MD, MPH ; Shah, S., MD; Kudenchuk, P.J., MD; Copass, M.K., MD; Cobb, L.A, MD
Annals of Emergency Medicine, 2005, Vol. 46, No. 2, pp. 132-141

Objective: To evaluate the result of rhythm reanalysis immediately after defibrillation shock, stacked shocks, and initial post-shock pulse checks in relation to achieving a pulse and starting CPR.

Methods: An observational study was done on 184 ventricular fibrillation patients. Data was collected from EMS written, electronic AED, dispatch audio and hospital/death certificate records. The AED records were analyzed in order to determine amount of VF patients who were defibrillated and attained pulse. This was analyzed according to single versus stacked shock, proportion of patients with a pulse during the first post-defibrillation pulse check, and from first shock to CPR.

Results and Discussion: After the first AED shock, 84% of the VF cases were terminated. An additional 8% of the VF cases were terminated after the second shock. Finally, the third shock terminated a further 5% of the VF cases. The first sequence of 3 shocks failed to terminate VF in 4% of the total cases.

Note that the termination of VF was not synonymous with the return of a pulse in the study. The first shock produced a detectable pulse in 22% (105/481) of the cases, whereas stacked shocks produced a pulse in 11% (13/122) of the cases. In total, the pulse returned in 25% (118/481) of the VF patient cases. However, during the initial post-shock pulse check, the pulse was only identified in 2.5% (12/481) of the cases. Thus, the authors interpret the rhythm reanalyzes as benefiting 1 of 50 patients, but harming the other 49 patients by delaying CPR.

Because of time spent on rhythm reanalysis, stacked shocks, and post-shock pulse checks, CPR after the first shock was not started before a median of 29 seconds.

Conclusion: AED rhythm reanalyzes, stacked shocks, and post-shock pulse checks resulted in very low outcomes for detecting return of pulse. Moreover, these AED procedures delayed the initiation of CPR. Hence, CPR was not initiated until 29 seconds after first shock.

Interruptions of Chest Compressions During Emergency Medical Systems Resuscitation

Valenzuela, D.T., MD; Kern, K.B., MD; Clark, L.L., BS; Berg, R.A., MS; Berg, M.D., MS; Berg, D.D.; Hilwig, R.W., DVM, PhD; Otto, C.W., MD; Newburn, D., BS; Ewy, G.A., MD
Circulation, 2005, Vol. 112, pp. 1259-1265

Objective: To investigate whether interruptions of chest compressions occur commonly and for substantial periods during treatment of out-of-hospital cardiac arrest.

Methods: 61 out-of-hospital cardiac arrests were studied. The data collection and the analysis was done by the use of Lifepak 500 AED, Lifepak 12 (Medtronic Emergency Response Systems), and computers. The monitor-defibrillator units were equipped with event documentation capacity that recorded the cardiac rhythms during each arrest. The methodology of using the Lifepak 12 AED continuous ECG record for determining chest compressions was validated with a post hoc porcine study.

Results: The table below describes the most important results. The first 5 minutes of results are especially important because many of these patients have been in cardiac arrest for 6-12 minutes before the arrival of EMS personnel. The total time from calling 911 to initiation of defibrillation or chest compression was 7 minutes and 33 seconds.

During the first 5 minutes, chest compressions were only performed 40% of the time during the resuscitation effort. Over the entire effort, chest compressions were performed 43% of the time. Furthermore, chest compressions were generally not started when the EMS personnel arrived. When initiated, the compressions were often interrupted for other resuscitation tasks. The average period with compressions during the first 5 minutes was 46 seconds and 55 seconds over the entire resuscitation effort. The median time interval from arrival to the patient's side until starting chest compressions was 78 seconds.

Overall, 7% of the patients survived to hospital discharge. These patients had a higher rate of initial VF rhythm and witnessed bystander CPR compared to the non-survivors.

Variable	First Five Minutes	Entire Effort	P
Time with Chest Compressions (CCs)	40±21	43±18	NS
Time without CCs	60±21	57±18	NS
Longest Period with CCs, Seconds	65 (46,84)	122 (68,206)	0.0001
Average Period with CCs, Seconds	46 (30,67)	55 (43,74)	NS
Longest Period without CCs, Seconds	95 (70,147)	172 (109, 246)	0.0001
Average Period without CCs, Seconds	56 (41,87)	57 (40,78)	NS

Conclusion: Professional EMS providers perform chest compressions less than half the time during resuscitation efforts of out-of-hospital cardiac arrest patients.



Quality of CPR Can Be Improved by Feedback

Basic CPR is one of the few therapies that is performed in the field without any “objective” feedback on performance. This section presents evidence that when feedback is provided to rescuers during CPR on manikins, their performance can actually be improved. There is mounting evidence that the performance of CPR is critical, quality of CPR matters and current CPR quality by healthcare professionals suffers. A way to improve the quality of CPR should be seen as a vital area of attention to help improve survival rates from Sudden Cardiac Arrest (SCA).

- i. Wik et al. (2001), Resuscitation, “An Automated Voice Advisory Manikin System for Training in Basic Life Support without an Instructor. A Novel Approach to CPR Training”
- ii. Wik et al. (2002), Resuscitation, “Retention of Basic Life Support Skills Six Months after Training with an Automated Voice Advisory Manikin System without Instructor Involvement”
- iii. Handley and Handley et al. (2003), Resuscitation, “Improving CPR Performance using an Audible Feedback System Suitable for Incorporation into an Automated External Defibrillator”
- iv. Hostler et al. (2005), Prehospital Emergency Care, “The Effect of a Voice Advisory Manikin (VAM) System on CPR Quality Among Prehospital Providers”
- v. Chiang et al. (2005), Resuscitation, “Better Adherence to the Guidelines During Cardiopulmonary Resuscitation through the Provision of Audio-prompts”
- vi. Wik et al. (2005), Resuscitation, “Twelve-month Retention of CPR Skills with Automatic Correcting Verbal Feedback”

An Automated Voice Advisory Manikin System for Training in Basic Life Support Without an Instructor. A Novel Approach to CPR Training

Wik, L.; Thowsen, J.; Steen, P.A.
Resuscitation, 2001, 50, pp. 167-172

Objective: To test if an automatic Voice Advisory Manikin (VAM) with a CPR feedback system can be used to improve the basic CPR quality of paramedic students.

Methods: 24 paramedic students were tested. The students were divided into two groups, 12 in each group. Group 1 performed CPR on a manikin for 3 minutes, without any feedback, followed by 3 minutes of CPR with feedback (after a 2 minute pause). Group 2 performed the two 3-minute periods in the reverse order. For both groups all ventilation and chest compressions were continuously recorded and were evaluated according to the European Resuscitation Council and the American Heart Association guidelines for CPR.

Results: For group 1 (Figure 1), with feedback in 2nd 3-minute round of CPR, correct inflations increased from 2% to 64% and the percentage of inflations too fast decreased from 94% to 25%. Correct depth of chest compressions increased from 32% to 92%.

Fig1: Improved CPR w/ Feedback

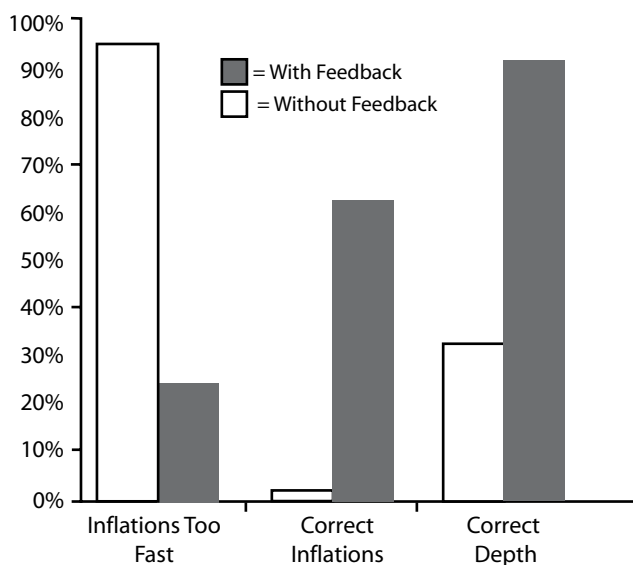
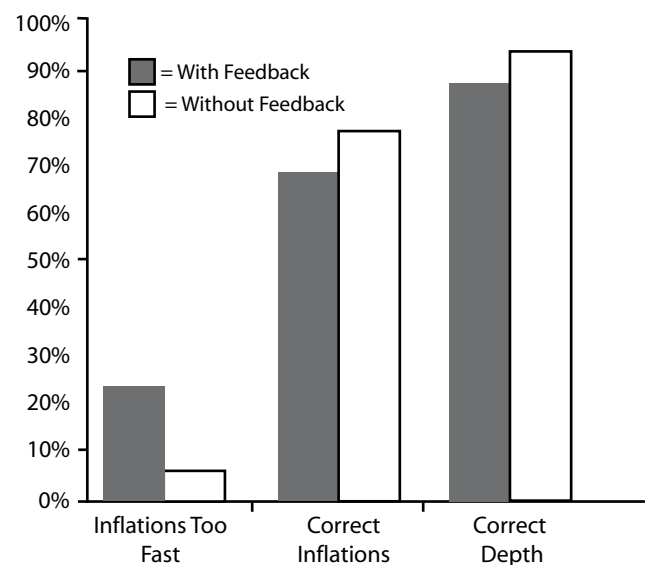


Fig2: Improved Retention w/ Feedback



For group 2 (Figure 2), with feedback in the 1st 3-minute round of CPR, the percentage of correct inflations and percentage of correct chest compression depth all improved during the first 3 minute CPR with feedback. In the second period, without feedback, there was no significant change in correct inflations. However, there was a deterioration tendency between the first and second period, and the percentage of correct compressions did not change during this period.

Conclusion: Feedback can (almost immediately) improve the basic CPR skills performance of paramedic students. In addition, when students begin with feedback, they attain a high level of performance and maintain that high level even when feedback is taken away.

Retention of Basic Life Support Skills Six Months After Training with an Automated Voice Advisory Manikin System Without Instructor Involvement

Wik, L.; Myklebust, H.; Auestad, B.H.
Resuscitation, 2002, 52, pp. 273-279

Objective: To evaluate the retention of BLS skills 6 months after training of ventilation and chest compressions on a manikin with a computer based on-line Voice Advisory Manikin (VAM) (feedback) system. Possible effects of initial overtraining were also studied.

Methods: 35 individuals, without any medical background, were studied on a standard Skillmeter™ Resusci® Anne connected to a laptop computer. The participants were given 20 minutes provisional CPR training on the VAM without an instructor. The use of the VAM allowed appropriate feedback to be given depending on the performance measured by VAM software, versus set limits for the ventilation and compression variables. In addition, one further group was randomized to receive ten similar 3 minute training sessions during one week in the following month ("overtrained group"). The participants were studied five times: (1) without feedback at a baseline; (2) without feedback immediately after 20 minutes of training with VAM; (3) with VAM immediately thereafter; (4) without VAM 6 months after training and; (5) with VAM 6 months and 1 week after training.

Results: Initial training improved all the CPR variables (see table). Correct inflations increased from a mean 9% to 58%, correct compression depth increased from a mean of 33% to 77%, and compression rate per minute increased from 90 to 108.

Time After Training	Baseline	Immediate Thereafter		Six Months		Six Months, One Week	
VAM*	No	No	Yes	No	Yes		
Group:	All	All	All	Controls	Overtrained	Controls	Overtrained
Number of subjects	35	35	35	21	12	18	12
Correct inflations	9 ± 20	58 ± 30	71 ± 27	18 ± 26	42 ± 38	58 ± 27	67 ± 28
Inflations too fast	81 ± 32	23 ± 27	16 ± 22	67 ± 30	40 ± 40	33 ± 24	19 ± 24
Inflations per minute	7 ± 2	7 ± 1	7 ± 1	7 ± 2	7 ± 1	7 ± 1	7 ± 1
Correct compression depth	33 ± 34	77 ± 30	91 ± 8	46 ± 33	61 ± 41	81 ± 19	87 ± 11
Compression rate per min	90 ± 25	108 ± 7	108 ± 7	92 ± 17	105 ± 9	101 ± 11	105 ± 6
Compression per min	46 ± 12	52 ± 4	52 ± 4	44 ± 12	49 ± 5	48 ± 5	51 ± 5
Compression part duty cycle	40 ± 6	45 ± 4	45 ± 4	42 ± 6	48 ± 6	44 ± 5	49 ± 7
Incomplete release	2 ± 9	4 ± 9	3 ± 9	2 ± 5	20 ± 27	6 ± 16	17 ± 26
Hand position too low	8 ± 20	0 ± 0	0 ± 0	9 ± 24	2 ± 4	9 ± 24	8 ± 17

After 6 months, the results for the controls group were not very different from the pre-training group. Though after 6 months, the participants had higher correct inflations (18%). The overtrained group had better retention of skills with respect to correct compression depth (mean 61%) and inflations (mean 42%). With VAM, both the compressions and ventilations improved instantly. That is, for the immediate testing and for the 6 months after the initial training session.

Conclusion: The use of a computer-based Voice Advisory Manikin (VAM) feedback system can improve basic life support CPR skills immediately. Moreover, VAM can promote better long-term retention with CPR overtraining.

Improving CPR Performance Using an Audible Feedback System Suitable for Incorporation Into an Automated External Defibrillator

Handley, A. J. and Handley, S. A. J.
Resuscitation, 2003, 57: pp. 57-62

Objective: To determine if a feedback system could improve the quality of CPR delivered by trained nurses.

Methods: The study included 36 general nurses performing CPR on a standard Skillmeter™ Resusci® Anne connected to a laptop. The manikin ran an experimental software program, which allowed on-line recording of the variables for ventilation and compression that were performed on the manikin. The Voice Advisory Manikin (VAM) system allowed limits to be set for the CPR variables. Corrective verbal feedback was given to the nurses performing CPR when not adhering to the European Resuscitation Council (ERC) guidelines for performing CPR.

First, the nurses performed 3 minutes of CPR on the VAM system. Thereafter, the nurses were randomly allocated to a control or a feedback group. Both groups performed two periods of CPR, but it was only the feedback group that received (corrective verbal) feedback in the second 3 minute period of CPR. For the control group, there were no statistically significant differences between the first and the second period of CPR with respect to the CPR variables.

Results: The table below shows there were significant improvements, with feedback, for percentage correct inflations and correct depth of chest compressions. There were also significant reductions in the average number of inflations and chest compressions. Despite the improvements, the feedback group had only 14% correct inflations and 56% correct chest compressions, when compared to the European Resuscitation Council (ERC) guidelines.

Results of 1st and 2nd 3 Minute Performances of CPR for the Feedback Group

Variable	Initial Test Mean	Second Test VAM Mean
Correct inflations	5.8%	13.9%
Inflation too much	53.8%	24.6%
Correct compression depth	32.3%	56%
Average Inflations per minute (Last 1 minute)	6.3%	5.4%
Average compression per minute (Last 1 minute)	50.8%	44.7%

Note: Rounded numbers

Conclusion: The feedback system used in the study improved the quality of CPR delivered by trained nurses. Even trained healthcare personnel do not retain their CPR skills. The authors state "...the study suggests that if the system (feedback) were to be incorporated into an AED, it could lead to better performance of CPR during a resuscitation attempt."

The Effect of a Voice Advisory Manikin (VAM) System on CPR Quality Among Prehospital Providers

Hostler, D., PhD, NREMT-P; Wang, W., MD, MPH; Parrish K., RN, EMT-P; Platt, T.E.; M.ED., NREMT-P, Guimond, G., BS, NREMT-P
Prehospital Emergency Care, 2005, Vol. 9, No. 1, pp. 53-60

Objective: To investigate if a Voice Advisory Manikin (VAM) system would improve the CPR performance by prehospital providers.

Methods: The study included 114 prehospital providers who performed two 3-minute one-rescuer periods of CPR on the VAM system; one period with the feedback turned off, and one period with the feature turned on.

Results: As can be seen from the table, VAM prompting did not directly result in correct compressions. Nevertheless, with VAM turned off, there was decrease in the percentage of correct compressions. This decrease was not an issue with audio prompts turned on. There was a small increase in the compression depth over the period, especially when the VAM feedback was on. Correct inflations decreased with the VAM prompting, but much more so with the prompting turned off. With respect to the tidal volume, there was a continuous increase over the 3-minute period, both with and without VAM feedback.

Compression and Ventilation Variables Measured Over Three Minutes of CPR With and Without Voice Advisory Manikin (VAM) Feedback

Parameter	VAM Feedback	30 Seconds	45 Seconds	60 Seconds	75 Seconds	90 Seconds
Correct Compressions	On	56.5 ± 34.1	58.4 ± 32.3	60.0 ± 32.5	62.9 ± 33.0	64.7 ± 33.4
	Off	56.0 ± 34.0	54.5 ± 32.4	53.1 ± 32.6	52.3 ± 33.1	50.9 ± 33.4
Compressions Depth (mm)	On	40.6 ± 8.8	41.4 ± 6.3	41.2 ± 6.0	41.5 ± 5.6	41.7 ± 5.2
	Off	40.4 ± 9.1	41.1 ± 7.1	41.2 ± 7.1	41.2 ± 7.3	40.9 ± 7.8
Correct Inflations (%)	On	61.3 ± 31.2	54.9 ± 30.7	57.3 ± 28.0	56.5 ± 28.5	57.0 ± 28.5
	Off	70.6 ± 31.2	63.9 ± 30.2	57.6 ± 27.4	54.6 ± 28.2	52.4 ± 28.3
Tidal Volume (ml)	On	626 ± 385	674 ± 351	689 ± 334	702 ± 339	703 ± 330
	Off	596 ± 376	630 ± 350	630 ± 334	667 ± 342	686 ± 337

Parameter	VAM Feedback	105 Seconds	120 Seconds	135 Seconds	150 Seconds	165 Seconds	180 Seconds
Correct Compressions	On	66.8 ± 32.8	68.1 ± 32.4	68.5 ± 32.0	69.4 ± 31.9	68.3 ± 33.2	68.0 ± 35.0
	Off	52.0 ± 32.8	52.1 ± 32.4	52.1 ± 32.1	52.0 ± 32.0	50.1 ± 33.2	48.8 ± 35.0
Compressions Depth (mm)	On	41.9 ± 5.0	41.9 ± 4.8	41.8 ± 4.6	41.8 ± 4.3	42.0 ± 4.2	41.9 ± 4.0
	Off	40.6 ± 8.5	40.5 ± 9.5	40.4 ± 10.6	40.3 ± 11.7	40.0 ± 12.9	39.7 ± 14.2
Correct Inflations (%)	On	58.4 ± 29.2	59.8 ± 29.2	59.3 ± 29.4	63.6 ± 25.7	59.8 ± 26.7	58.8 ± 27.7
	Off	52.3 ± 29.4	51.8 ± 29.3	52.1 ± 30.0	52.0 ± 27.0	49.1 ± 28.3	47.9 ± 29.6
Tidal Volume (ml)	On	715 ± 311	721 ± 301	723 ± 285	721 ± 285	724 ± 289	733 ± 286
	Off	696 ± 319	710 ± 310	712 ± 294	709 ± 295	721 ± 298	725 ± 296

Conclusion: Over a period of 3-minute one-rescuer CPR, verbal feedback prevents decrease of chest compression and ventilation performance.

Better Adherence to the Guidelines During Cardiopulmonary Resuscitation Through the Provision of Audio-Prompts

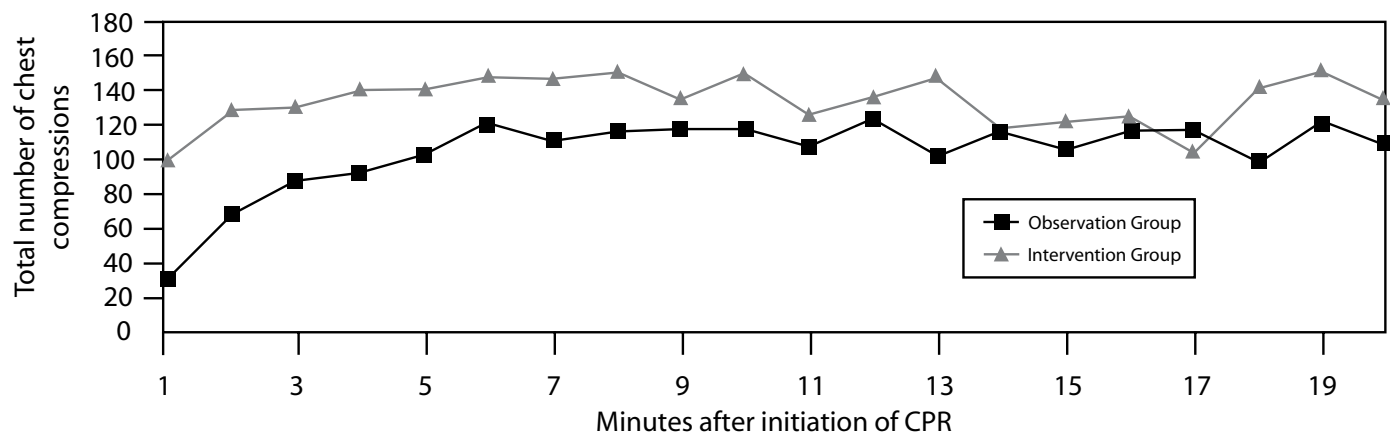
Chiang, W.; Chen, W.; Chen, S.; Ko, P.C.; Lin, C.; Tsai, M.; Chang, W.; Chen, S.; Tsan, C.; Ma, M.H. Resuscitation, 2005, 64: pp. 297-301

Objective: To identify the deficiencies in the clinical practice of resuscitation through motion analysis of video-recorded CPR, and to evaluate the improvement of CPR quality by the use of audio-prompt methods.

Methods: Thirty patients were divided in two groups: 17 patients in an observational group and 13 patients in an intervention group. In the observational group (analyzed through motion analysis of video recorded CPR), three major inconsistencies were found between clinical CPR practice and the current guidelines; (1) too few chest compressions per minute; (2) too long and unnecessary hands-off periods; and (3) intubation times longer than 20 seconds without re-oxygenation by a bag-valve-mask. In the intervention group it was attempted to correct these three major inconsistencies to CPR guidelines by audio-prompt methods (through a metronome at 100 bleeps per min and a siren every 20 seconds).

Results: As illustrated by figure 1, especially during the first 2 minutes, the intervention group exhibited a much shorter hands-off time, compared to the observation group.

Fig 1: Total Number of Chest Compressions in Observation vs. Intervention Group



From Figure 2 we see that after the first 2-3 minutes, both groups reached a baseline level of hands-off time.

Fig 2: Average Hands-off Time in Observation vs. Intervention Group

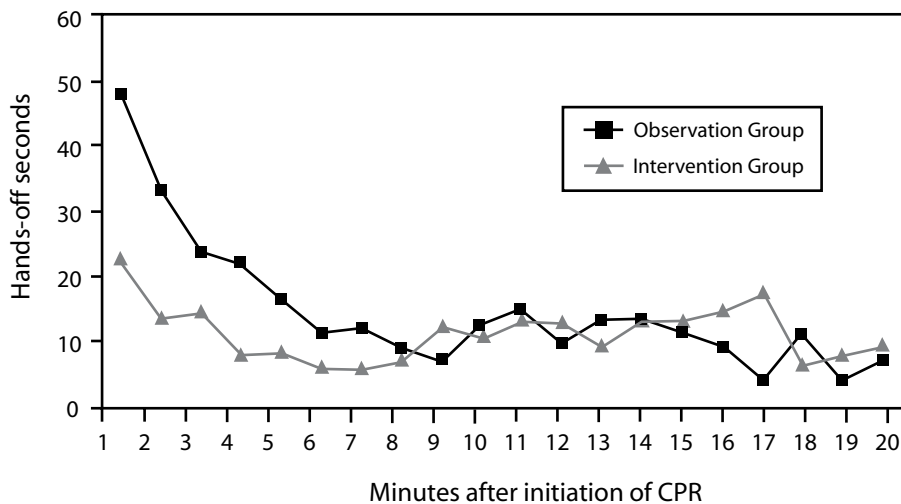
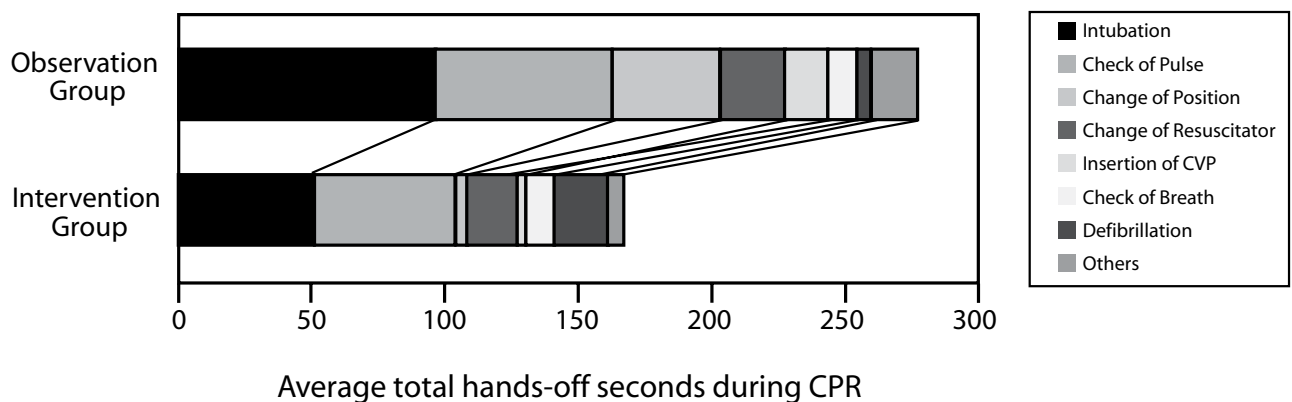


Figure 3 presents the hands-off periods among the two groups. With respect to the issue of intubation times longer than 20 seconds without re-oxygenation by a bag-valve-mask, it can be seen from Figure 3 that intubation times were significantly reduced by audio-prompts, along with the other variables.

Fig 3: Analysis of Hands-off Periods



Conclusion: Feedback can improve the adherence to CPR guidelines in the clinical setting. The authors state: *“To the best of our knowledge, our study is the first to indicate that audio-prompt techniques applied in actual resuscitation can improve adherence to the guidelines on chest compression rates, intubation time, and hands-off periods.”*

Twelve-Month Retention of CPR Skills with Automatic Correcting Verbal Feedback

Wik, L.; Myklebust, H.; Auestad, B.H.,
Resuscitation, 2005, Vol. 66, Issue 1, pp. 27-30

Objective: To evaluate the twelve-month retention of CPR skills after initial CPR training. (A follow-up study to the six-month retention study published in Resuscitation, 2002, vol. 52.)

Methods: 35 volunteers performed 20 minutes of individual training, without an instructor, on a computer-based voice advisory feedback system (VAM).^{*} The feedback given depended on CPR performance versus set limits for compressions and ventilations. Twelve of the participants received an additional ten 3-minute self-training sessions one month after the initial individual training. All the participants were now tested 12 months after the initial training with feedback.

Results: There were no significant changes in CPR skills when the volunteers were tested with active feedback 12 months after initial training session with activated feedback versus immediate feedback or 6 month training. However, there was a slightly lower number of compressions per minute at 12 months versus immediate post-training in the subgroup with 20 minutes of initial training (47 compressions per minute versus 52). There were no differences between the 20 minute and 50 minute training subgroups at 12 months.

Time after Training	Baseline	Immediate Thereafter	Six Months		Twelve Months	
VAM*	No	No	No		Yes	
Group:	All	All	20 Minutes	50 Minutes	20 Minutes	50 Minutes
Study period	1	2	3	3	4	4
Number of subjects	35	35	18	12	16	12
Correct inflations	9±20	71±27	56±27	67±28	62±25	75±23
Inflations too fast	81±32	16±22	33±24	19±24	20±14	17±21
Inflations / minute	6±2	7±1	7±1	7±1	7±1	7±1
Correct compression depth	32±33	91±8	81±19	87±11	87±9	88±12
Compression rate (minute)	91±26	108±7	101±11	105±6	101±8	102±8
Compression (minute)	45±15	52±4	49±5	51±5	47±4	49±4
Compression part duty cycle	38±9	45±4	44±5	49±7	43±6	46±4
Incomplete release	2±9	3±9	6±16	17±26	11±27	16±26
Hand position too low	8±20	0±0	7±24	7±17	5±16	11±27

Conclusion: A computer-based voice advisory feedback system can improve the basic life support CPR skills on a manikin with no worsening in feedback supported performance after 12 months.

References

Quality of CPR Has an Impact on Survival

Bystander CPR

- i. Bossaert and Van Hoeyweghen et al. (1989), Resuscitation, "Bystander Cardiopulmonary Resuscitation (CPR) in Out-of-Hospital Cardiac Arrest"
- ii. Van Hoeyweghen, R. J.; Bossaert L. L; Mullie, A.; Calle, P.; Martens, P.; Buylaert, W.A., Delooz, H., Belgian Cerebral Resuscitation Study Group et al. (1993), Resuscitation, "Quality and Efficiency of Bystander CPR"
- iii. Wik et al. (1994), Resuscitation, "Quality of Bystander Cardiopulmonary Resuscitation Influences Outcome after Prehospital Cardiac Arrest"
- iv. Gallagher et al. (1995), JAMA, "Effectiveness of Bystander Cardiopulmonary Resuscitation and Survival Following Out-of-Hospital Cardiac Arrest"
- v. Herlitz, J.; Svensson, L.; Holmberg, S.; Ångquist, K; Young, M. et al. (2005), Resuscitation, "Efficacy of Bystander CPR: Intervention by Lay People and by Healthcare Professionals"

Professional CPR

- i. Aufderheide et al. (2004), Circulation, "Hyperventilation-induced during Cardiopulmonary Resuscitation"
- ii. Ko et al. (2005), Resuscitation, "Evaluating the Quality of Prehospital Cardiopulmonary Resuscitation by Reviewing Automated External Defibrillator Records and Survival for Out-of-Hospital Witnessed Arrests"

CPR Before First Shock Can Improve Survival

- i. Cobb et al. (1999), JAMA, "Influence of Cardiopulmonary Resuscitation Prior to Defibrillation in Patients with Out-of-Hospital Ventricular Fibrillation"
- ii. Weisfeldt et al. (2002), JAMA, "Resuscitation after Cardiac Arrest – A 3-phase Time-Sensitive Model"
- iii. Wik et al. (2003), JAMA, "Delaying Defibrillation to give Basic Cardiopulmonary Resuscitation to Patients With Out-of-Hospital Ventricular Fibrillation – A Randomized Trial"
- iv. Vilke et al. (2005), Resuscitation, "The Three-phased Model of Cardiac Arrest as Applied to Ventricular Fibrillation in a Large, Urban Emergency Medical Service System"

Quality of CPR by Healthcare Professionals

- i. Abella et al. (2005), JAMA, "Quality of Cardiopulmonary Resuscitation During In-hospital Cardiac Arrest"
- ii. Abella et al. (2005), Circulation, "Chest Compressions Rates During Cardiopulmonary Resuscitation are Suboptimal – A Prospective Study During In-hospital Cardiac Arrest"
- iii. Wik et al. (2005), JAMA, "Quality of Cardiopulmonary Resuscitation During Out-of-Hospital Cardiac Arrest"

Quality of CPR Can Be Improved by Less Hands-off Time

- i. Eftestool et al. (2002), Circulation, "Effects of Interrupting Precordial Compressions on the Calculated Probability of Defibrillation Success During Out-of-Hospital Cardiac Arrest"
- ii. Steen et al. (2003), Resuscitation, "The Critical Importance of Minimal Delay Between Chest Compressions and Subsequent Defibrillation: A Haemodynamic Explanation"
- iii. Van Alem et al. (2003), Annals of Emergency Medicine, "Interruption of Cardiopulmonary Resuscitation with the Use of the Automated External Defibrillator in Out-of-Hospital Cardiac Arrest"
- iv. Rea et al. (2005), Annals of Emergency Medicine, "Automated External Defibrillator: To What Extent Does the Algorithm Delay CPR"
- v. Venezuela et al. (2005), Circulation, "Interruptions of Chest Compressions During Emergency Medical Systems Resuscitation"

Quality of CPR Can Be Improved by Feedback

- i. Wik et al. (2001), Resuscitation, "An Automated Voice Advisory Manikin System for Training in Basic Life Support without an Instructor. A Novel Approach to CPR Training"
- ii. Wik et al. (2002), Resuscitation, "Retention of Basic Life Support Skills Six Months after Training with an Automated Voice Advisory Manikin System without Instructor Involvement"
- iii. Handley and Handley et al. (2003), Resuscitation, "Improving CPR Performance using an Audible Feedback System Suitable for Incorporation into an Automated External Defibrillator"
- iv. Hostler et al. (2005), Prehospital Emergency Care, "The Effect of a Voice Advisory Manikin (VAM) System on CPR Quality Among Prehospital Providers"
- v. Chiang et al. (2005), Resuscitation, "Better Adherence to the Guidelines During Cardiopulmonary Resuscitation through the Provision of Audio-prompts"
- vi. Wik et al. (2005), Resuscitation, "Twelve-month Retention of CPR Skills with Automatic Correcting Verbal Feedback"

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Q-CPR is a new technology platform developed by Laerdal to assist rescuers with providing guidelines-quality CPR during real-life emergencies. The technology was developed through great cooperation with leading research centers that share the same commitment to better understand how we can positively impact survival rates from sudden cardiac arrest. Furthermore, Q-CPR is a shared effort between Laerdal and Philips Medical Systems to integrate this new measurement and feedback technology into HeartStart defibrillators.

Q-CPR is a new clinical monitoring parameter that offers objective measurement and corrective feedback on compression depth and rate, as well as ventilation frequency and rate. It enables measurement and feedback of essential CPR parameters, as well as parameter logging for subsequent debriefing or analysis. Feedback is provided by both audible and visual cues to the rescuer. All feedback provided by the Q-CPR technology is based on recognized international guidelines for CPR.

For more information on Q-CPR, visit www.laerdal.com.

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