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HeartSine Technologies Ltd.

A Collection of Abstracts from Scientific Papers supporting HeartSine's CPR-Advisor Technology to improve outcomes from out-of-hospital Cardiac Arrest.

Research to support HeartSine Technologies CPR Advisor Technology.

Foreword.

Annual mortality rate from sudden cardiac arrest across Europe and North America exceeds 700,000. Since the early 1990's, the European Resuscitation Council (ERC) has called for innovative approaches to reduce time to cardiopulmonary resuscitation (CPR) and defibrillation to improve outcomes from sudden cardiac arrest. Despite recent developments in resuscitation practices, outcomes from cardiac arrests are still disappointing. Among survivors, neurological complications represent the leading cause of morbidity and disability. One of the key determinants in improving cerebral outcome during CPR is to sustain sufficient cerebral oxygenation at the cellular level.

Therefore in recent years' cardiopulmonary resuscitation, particularly the efficacy of chest compressions has been the focus of resuscitation therapy worldwide. The challenges in improving bystander CPR relate to both administration of effective chest compressions and prompt defibrillation. Manufacturers of live saving technologies must therefore facilitate the administration of effective bystander CPR. In order to meet the requirements of public access defibrillation programmes, the elimination of pulse checks and the emphasis on chest compressions rather than ventilations must be addressed. Further pre-clinical and clinical studies have been completed in addition to enhanced defibrillator design to improve CPR performance.

Introduction.

Whilst trained emergency responders are always in practice of their resuscitation and CPR skills, due to the nature of their work, a trained "layman" will rarely use the skills that they have learned, perhaps from a community scheme, in every day life. This raises issues regarding the retention of CPR skills in trained laymen, as studies show that retention is poor. HeartSine Technologies Ltd has dealt with this issue directly with the The HeartSine samaritan® PAD with CPR Advisor mom(EPTth

The effect of transport on quality of cardiopulmonary resuscitation in out-of-hospital cardiac arrest.

Introduction

Most manikin and clinical studies have found decreased quality of CPR during transport to hospital. We wanted to study quality of CPR before and during transport for out-of-hospital cardiac arrest patients and also whether quality of CPR before initiation of transport was different from the quality in patients only receiving CPR on scene.

Materials and methods

Quality of CPR was prospectively registered with a modified defibrillator for consecutive cases of out-of hospital cardiac arrest in three ambulance services during 2002–2005. Ventilationswere registered via changes in transthoracic impedance and chest compressions were measured with an extra chest compression pad placed on the patients' sternum. Paired t-tests were used to analyse quality of CPR before vs. during transport with ongoing CPR. Unpaired t-tests were used to compare CPR quality prior to transport to CPR quality in patients with CPR terminated on site.

Results

Quality of CPR did not deteriorate during transport, but as previously reported overall quality of CPR was substandard. Quality of CPR performed on site was significantly better when transport was not initiated with ongoing CPR compared to episodes with initiation of transport during CPR: fraction of time without chest compressions was 0.45 and 0.53 ($p < 0.001$), compression depth 37mm and 34mm ($p = 0.04$), and number of chest compressions per minute 61 and 56 ($p = 0.01$), respectively.

Conclusion

CPR quality was sub-standard both before and during transport. Early decision to transport might have negatively affected CPR quality from the early stages of resuscitation.

Silje Ødegaard, Theresa Olasveengen, Petter Andreas Steen, Jo Kramer-Johansen
Resuscitation 80 (2009) 843–848

Delaying Defibrillation to Give Basic Cardiopulmonary Resuscitation to Patients with Out-of-Hospital Ventricular Fibrillation: A Randomized Trial.

Objective

For patients with ventricular fibrillation, the chances of survival depend on early defibrillation. It has been suggested that, in patients who have been in ventricular fibrillation for a few minutes, cardiopulmonary resuscitation (CPR) before defibrillation might improve perfusion, thus enhancing the chances of survival. The effects of CPR before defibrillation were evaluated in patients with out-of-hospital ventricular fibrillation, including the influence of ambulance response time.

Methods

The randomized trial included 200 patients with ventricular fibrillation: response time was up to 5 minutes in 81 patients and longer than 5 minutes in 119. Patients were randomly assigned to standard care (ie, immediate defibrillation) or 3 minutes of CPR performed before defibrillation. In case of initially unsuccessful defibrillation, the duration of CPR before additional defibrillation attempts was 1 minute in the immediate-defibrillation group and 3 minutes in the delayed-defibrillation group. Survival to hospital discharge was the main study end point. In a planned analysis, this and other outcomes were compared for patients with response times of up to 5 minutes or longer than 5 minutes.

Results

The survival rate to hospital discharge was 15% for patients receiving immediate defibrillation and 22% for those receiving CPR first, a nonsignificant difference. The 2 groups were also similar in their rates of return of spontaneous circulation (56% in the immediate group and 46% in the delayed group) and in 1-year survival (20% and 15%, respectively). All outcomes were similar for patients with response times of up to 5 minutes. However, for those with longer response times, a return to spontaneous circulation was achieved in 58% of the CPR-first group, compared with 38% of the immediate-defibrillation group (odds ratio [OR] 2.22). For this subgroup, delaying defibrillation for CPR was associated with a better chance of survival to hospital discharge (OR 7.42) and of 1-year survival (OR 6.76). Of patients who survived to hospital discharge, 89% had no or only minor neurologic deficits.

Conclusions

For patients with out-of-hospital ventricular fibrillation and response times of 5 minutes or less, CPR before defibrillation does not improve the chances of survival. However, for those with longer response times, the CPR-first strategy appears to improve the chances of return of spontaneous circulation and of survival. Confirmatory randomized trials are needed.

Wik L, Hansen TB, Fylling F, et al
JAMA. 2003; 289:1389-1395

Effect of bystander cardiopulmonary resuscitation in out-of-hospital cardiac arrest patients in Sweden.

Background

Information from the Swedish Cardiac Arrest Registry was used to investigate: (a) The proportion of patients suffering an out-of-hospital cardiac arrest who were given bystander cardiopulmonary resuscitation (B-CPR). (b) Where and by whom B-CPR was given. (c) The effect of B-CPR on survival.

Method

A prospective, observational study of cardiac arrests reported to the Swedish Cardiac Arrest Registry. Analyses were based on standardised reports of out-of-hospital cardiac arrests from ambulance organisations in Sweden, serving 60% of the Swedish population. From 1983 to 1995, 15–20% of the population had been trained in CPR.

Results

Of 9877 patients, collected between January 1990 and May 1995, B-CPR was attempted in 36%. In 56% of these cases, the bystanders were lay persons and in 25% they were medical personnel. Most of the arrests took place at home (69%) and only 23% of these patients were given B-CPR in contrast to cardiac arrest in other places where 53% were given CPR. Survival to 1 month was significantly higher in all cases that received B-CPR (8.2 vs. 2.5%). The odds ratio for survival to 1 month with B-CPR was in a logistic regression analysis 2.5 (95% Confidence Interval 1.9–3.1).

Conclusions

In Sweden, the willingness and ability to perform B-CPR appears to be relatively widespread. More than half of B-CPR was performed by laypersons. B-CPR resulted in a two to threefold increase in survival.

Mikael Holmberg, Stig Holmberg, Johan Herlitz
Resuscitation 47 (2000) 59–70

Effectiveness of bystander cardiopulmonary resuscitation and survival following out-of-hospital cardiac arrest.

Objective

To examine the independent relationship between effectiveness of bystander cardiopulmonary resuscitation (CPR) and survival following out-of-hospital cardiac arrest.

Design

Prospective observational cohort.
Setting: New York City.
Participants: A total of 2071 consecutive out-of-hospital cardiac arrests meeting Utstein criteria.

Intervention

Trained pre-hospital personnel assessed the quality of bystander CPR on arrival at the scene. Satisfactory execution of CPR required performance of both adequate compressions and ventilations in conformity with current American Heart Association guidelines.

Main Outcome Measure

Adjusted association between CPR effectiveness and survival. Survival was defined as discharge from hospital to home.

Results

Outcome was determined on all members of the inception cohort-none were lost to follow-up. When the association between bystander CPR and survival was adjusted for effectiveness of CPR in the parent data set (N=2071), only effective CPR was retained in the logistic model (adjusted odds ratio [OR] = 5.7; 95% confidence interval [CI], 2.7 to 12.2; $P < 0.001$). Of the subset of 662 individuals (32%) who received bystander CPR, 305 (46%) had it performed effectively. Of these, 4.6% (14/305) survived vs 1.4% (5/357) of those with ineffective CPR (OR = 3.4; 95% CI, 1.1 to 12.1; $P < 0.02$). After adjustment for witness status, initial rhythm, interval from collapse to CPR, and interval from collapse to advanced life support, effective CPR remained dependently associated with improved survival (adjusted OR = 3.9; 95% CI, 1.1 to 14.0; $P < 0.04$).

Conclusion

The association between bystander CPR and survival in out-of hospital cardiac arrest appears to be confounded by CPR quality. Effective CPR is independently associated with a quantitatively and statistically significant improvement in survival.

Gallagher EJ, Lombardi G, Gennis P.
Resuscitation, Volume 32, Issue 1, July 1996, Page 77

The next few pages will provide a broad understanding of Impedance Cardiography (ICG) technology, and its uses in the world of resuscitation.

Below are the references for the following articles.

The transthoracic impedance cardiogram is a potential haemodynamic sensor for an automated external defibrillator.
PW Johnston, Z Imam, G Dempsey, J Anderson and AAJ Adgey.
European Heart Journal (1998) 19, 1879–1888

Assessment of the impedance cardiogram recorded by an automated external defibrillator during clinical cardiac arrest.
Nick Alexander Cromie, MD; John Desmond Allen, MD; Ce´ sar Navarro, PhD; Colin Turner, PhD; John McC Anderson, MPhil, DPhil; A. A. Jennifer Adgey, FACC.
Crit Care Med 2010; 38:510 –517

The impedance cardiogram recorded through two electrocardiogram/defibrillator pads as a determinant of cardiacarrest during experimental studies.
Nick Alexander Cromie, MD; John Desmond Allen, MD; Colin Turner, PhD; John McC Anderson, MPhil, DPhil; A. A. Jennifer Adgey, FACC.
Crit Care Med 2008; 36:1578–1584

The Impedance Cardiogram is an indicator of CPR effectiveness for out-of-hospital cardiac arrest victims.
Rebecca Di Maio.
Journal of the American College of Cardiology, Volume 55, Issue 10, Supplement 1, 9 March 2010, Page A217.E2062

The effect of transport on quality of cardiopulmonary resuscitation in out-of-hospital cardiac arrest.
Silje Ødegaard, Theresa Olasveengen, Petter Andreas Steen, Jo Kramer-Johansen.
Resuscitation 80 (2009) 843–848

The transthoracic impedance cardiogram is a potential haemodynamic sensor for an automated external defibrillator.

Aims

The American Heart Association has endorsed the concept of Public Access Defibrillation. However, there have been reports of inappropriate direct current shocks from automatic external defibrillators. The specificity of automatic external defibrillators for shockable rhythms may be improved by the incorporation of a haemodynamic sensor.

Methods and Results

This study examined the use of four parameters extracted from the impedance cardiogram i.e. peak dz/dt (the peak of the impedance cardiogram measured from the line dz/dt=0 Ùs"1), Peak-trough (the peak-to-trough measurement of the impedance cardiogram Ùs"1), Area 1 (the area under the C wave of the impedance cardiogram above the line dz/dt=0 mÙ) and Area 2 (the area under the impedance cardiogram 50 ms on either side of the Peak and above the line dz/dt=0 mÙ) as predictors of cardiac output.

At 116 cardiac arrest calls the ECG and impedance cardiogram were recorded through two ECG/defibrillator pads placed in an antero-apical position. Nine recordings were rejected for artefact. The rhythm recorded in the remaining 107 calls was asystole, ventricular fibrillation, agonal rhythm (20), electromechanical dissociation (22), ventricular tachycardia (27) and sinus rhythm (5). These rhythms were divided into those associated with haemodynamic collapse i.e. no pulse —asystole, ventricular fibrillation, agonal rhythm, electromechanical dissociation and shockable ventricular tachycardia (associated with loss of consciousness, pulseless or a systolic blood pressure of <80 mmHg) (Group 1) and those associated with a satisfactory cardiac output i.e. non-shockable ventricular tachycardia (conscious with a pulse) and sinus rhythm (Group 2).

On univariate analysis each of the four impedance cardiogram parameters were significantly greater in Group 2 than Group 1 (P<0·001). On multivariate analysis the parameters which best differentiated the two groups were Area 1 and Peak-trough.

Conclusion

Thus the impedance cardiogram is a potential haemodynamic sensor for an automatic external defibrillator.

European Heart Journal (1998) 19, 1879–1888
P. W. Johnston, Z. Imam, G. Dempsey, J. Anderson and A. A. J. Adgey

Assessment of the impedance cardiogram recorded by an automated external defibrillator during clinical cardiac arrest.

Objective

To assess the impedance cardiogram recorded by an automated external defibrillator during cardiac arrest to facilitate emergency care by lay persons. Lay persons are poor at emergency pulse checks (sensitivity 84%, specificity 36%); guidelines recommend they should not be performed. The impedance cardiogram (dZ/dt) is used to indicate stroke volume. Can an impedance cardiogram algorithm in a defibrillator determine rapidly circulatory arrest and facilitate prompt initiation of external cardiac massage?

Design

Clinical study.

Setting

University hospital.

Patients

Phase 1 patients attended for myocardial perfusion imaging. Phase 2 patients were recruited during cardiac arrest. This group included non-arrest controls.

Interventions

The impedance cardiogram was recorded through defibrillator/electrocardiographic pads oriented in the standard cardiac arrest position.

Measurements and Main Results

Phase 1 / Stroke volumes from gated myocardial perfusion imaging scans were correlated with parameters from the impedance cardiogram system (dZ/ dtmax and the peak amplitude of the Fast Fourier Transform of dZ/dt between 1.5 Hz and 4.5 Hz). Multivariate analysis was performed to fit stroke volumes from gated myocardial perfusion imaging scans with linear and quadratic terms for dZ/dtmax and the Fast Fourier Transform to identify significant parameters for incorporation into a cardiac arrest diagnostic algorithm. The square of the peak amplitude of the Fast Fourier Transform of dZ/dt was the best predictor of reduction in stroke volumes from gated myocardial perfusion imaging scans (range _ 33–85 mL; p _ .016). Having established that the two pad impedance cardiogram system could detect differences in stroke volumes from gated myocardial perfusion imaging scans, we assessed its performance in diagnosing cardiac arrest.

Phase 2 / The impedance cardiogram was recorded in 132 “cardiac arrest” patients (53 training, 79 validation) and 97 controls (47 training, 50 validation): the diagnostic algorithm indicated cardiac arrest with sensitivities and specificities (_ exact 95% confidence intervals) of 89.1% (85.4 –92.1) and 99.6% (99.4 –99.7; training) and 81.1% (77.6– 84.3) and 97% (96.7–97.4; validation).

Conclusions

The impedance cardiogram algorithm is a significant marker of circulatory collapse. Automated defibrillators with an integrated impedance cardiogram could improve emergency care by lay persons, enabling rapid and appropriate initiation of external cardiac massage.

Nick Alexander Cromie, MD; John Desmond Allen, MD; Ce´ sar Navarro, PhD; Colin Turner, PhD; John McC Anderson, MPhil, DPhil; A. A. Jennifer Adgey, FACC

Crit Care Med 2010; 38:510 –517

Effectiveness of bystander cardiopulmonary resuscitation and survival following out-of-hospital cardiac arrest.

Objective

To examine the independent relationship between effectiveness of bystander cardiopulmonary resuscitation (CPR) and survival following out-of-hospital cardiac arrest.

Design

Prospective observational cohort. Setting: New York City. Participants: A total of 2071 consecutive out-of-hospital cardiac arrests meeting Utstein criteria.

Intervention

Trained pre-hospital personnel assessed the quality of bystander CPR on arrival at the scene. Satisfactory execution of CPR required performance of both adequate compressions and ventilations in conformity with current American Heart Association guidelines.

Main Outcome Measure

Adjusted association between CPR effectiveness and survival. Survival was defined as discharge from hospital to home.

Results

Outcome was determined on all members of the inception cohort-none were lost to follow-up. When the association between bystander CPR and survival was adjusted for effectiveness of CPR in the parent data set (N=2071), only effective CPR was retained in the logistic model (adjusted odds ratio [OR] = 5.7; 95% confidence interval [CI], 2.7 to 12.2; $P < 0.001$). Of the subset of 662 individuals (32%) who received bystander CPR, 305 (46%) had it performed effectively. Of these, 4.6% (14/305) survived vs 1.4% (5/357) of those with ineffective CPR (OR = 3.4; 95% CI, 1.1 to 12.1; $P < 0.02$). After adjustment for witness status, initial rhythm, interval from collapse to CPR, and interval from collapse to advanced life support, effective CPR remained dependently associated with improved survival (adjusted OR = 3.9; 95% CI, 1.1 to 14.0; $P < 0.04$).

Conclusion

The association between bystander CPR and survival in out-of hospital cardiac arrest appears to be confounded by CPR quality. Effective CPR is independently associated with a quantitatively and statistically significant improvement in survival.

Gallagher EJ, Lombardi G, Gennis P.
Resuscitation, Volume 32, Issue 1, July 1996, Page 77

The impedance cardiogram recorded through two electrocardiogram/defibrillator pads as a determinant of cardiacarrest during experimental studies.

Objective

Laypersons are poor at emergency pulse checks (sensitivity 84%, specificity 36%). Guidelines indicate that pulse checks should not be performed. The impedance cardiogram (dZ/dt) is used to assess stroke volume. Can a novel defibrillator based impedance cardiogram system be used to distinguish between circulatory arrest and other collapse states?

Design

Animal study.

Setting

University research laboratory.

Subjects

Twenty anesthetized, mechanically ventilated pigs, weight 50–55 kg.

Interventions

Stroke volume was altered by right ventricular pacing (160, 210, 260, and 305 beats/min). Cardiac arrest states were then induced: ventricular fibrillation (by rapid ventricular pacing) and, after successful defibrillation, pulseless electrical activity and asystole (by high-dose intravenous pentobarbitone).

Measurements and Main Results

The impedance cardiogram was recorded through electrocardiogram/defibrillator pads in standard cardiac arrest positions. Simultaneously recorded electro- and impedance cardiogram (dZ/dt) along with arterial blood pressure tracings were digitized during each pacing and cardiac arrest protocol. Five-second epochs were analyzed for sinus rhythm (20 before ventricular fibrillation, 20 after successful defibrillation), ventricular fibrillation (40), pulseless electrical activity (20), and asystole (20), in two sets of ten pigs (ten training, ten validation). Standard impedance cardiogram variables were noncontributory in cardiac arrest, so the fast Fourier transform of dZ/dt was assessed. During ventricular pacing, the peak amplitude of fast Fourier transform of dZ/dt (between 1.5 and 4.5 Hz) correlated with stroke volume (r2 _ .3, p < .001). In cardiac arrest, a peak amplitude of fast Fourier transform of dZ/dt of <4 dB·ohm·rms indicated no output with high sensitivity (94% training set, 86% validation set) and specificity (98% training set, 90% validation set).

Conclusions

As a powerful clinical marker of circulatory collapse, the fast Fourier transformation of dZ/dt (impedance cardiogram) has the potential to improve emergency care by laypersons using automated defibrillators.

Nick Alexander Cromie, MD; John Desmond Allen, MD; Colin Turner, PhD; John McC Anderson, MPhil, DPhil; A. A. Jennifer Adgey, FACC

Crit Care Med 2008; 36:1578–1584

The impedance cardiogram is an indicator of CPR effectiveness for out-of-hospital cardiac arrest victims.

Background

The ERC guidelines place a greater emphasis on the importance of external cardiac massage and advocate the prompt initiation of effective bystander CPR to significantly reduce mortality due to out-of-hospital CA. An algorithm has been developed which utilizes distinctive features in the impedance cardiogram (ICG) to ensure effective chest compressions are administered by the operator.

Methods

At the time of cardiac arrest the HeartSine AED was applied using AED electrodes adhered to the chest wall to the right of the upper sternum and over the cardiac apex. The ECG, ICG and any CPR were recorded electronically for downloading later using the data recovery unit. Thresholds were pre-determined following retrospective analysis of 170 cases of CPR. The amplitude of the ICG signal, if outside the minimum threshold, was classified as CPR. Sensitivity and specificity scores were calculated as shown below in table 1.

Results

CPR Criteria	ICG Test Sample Size	Performance Specifications (%)	Performance Results (%)	90% One-Sided Lower Confidence Limit (%)
(ICG_SPEED) Adequate	82377	Sensitivity: > 90 Specificity: > 90	Sensitivity: 95.38 Specificity: 93.11	Sensitivity: 83.40 Specificity: 82.19
(ICG_FORCE) Adequate	108728	Sensitivity: > 90 Specificity: > 90	Sensitivity: 99.96 Specificity: 98.47	Sensitivity: 99.54 Specificity: 96.29

Table 1

Sensitivity and Specificity results based on both speed and force of CPR.

Conclusion

Both the ICG_FORCE and ICG_SPEED CPR management tools will enhance CPR efficacy for both lay users and minimally trained bystanders by continuously advising on the quality of the compressions administered. The administration of effective chest compressions can significantly reduce the chances of neurological impairment due to inadequate cerebral oxygenation following a CA. The above results merit further investigation using ICG to develop an algorithm to detect the presence of a pulse.

Di Maio R, Navarro C, Cromie NA, Anderson J, Adgey JAA.

Journal of the American College of Cardiology, Volume 55, Issue 10, Supplement 1, 9 March 2010, Page A217.E2062

The effect of transport on quality of cardio-pulmonary resuscitation in out-of-hospital cardiac arrest.

For further information and in-depth knowledge of CPR and ICG, the following articles are easily accessible through the web and highly recommended.

CPR Related

Quality and efficiency of bystander CPR. Belgian Cerebral Resuscitation Study Group, Van Hoeyweghen RJ, Bossaert LL et al. Resuscitation. 26(1):47-52, 1993

Influence of Cardiopulmonary Resuscitation Prior to Defibrillation in Patients With Out-of-Hospital Ventricular Fibrillation, L Cobb, C Fahrenbruch, Lt T Walsh, M Copass, M Olsufka, M Breskin, A Hallstrom. JAMA. 281, 1182-1188, 1999

Increasing Use of Cardiopulmonary Resuscitation During Out-of-Hospital Ventricular Fibrillation Arrest: Survival Implications of Guideline Changes, Rea et al. Circulation.114, 2760-2765, 2006

Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: A prospective interventional study, J Kramer-Johansen, H Myklebust, L Wik, B Fellows, L Svensson, H Sørebø, P Steen. Resuscitation. 71, 283-292, 2006

ICG Related:

Impedance Cardiography as a non invasive method of monitoring cardiac function and other parameters of the cardiovascular system. W. G. Kubicek, R. P. Patterson, D. A. Witsoe. Annals of the New York Academy of Sciences. Volume 170 Issue International Conference on Bioelectric Impedance, Pages 724 – 732, 1970.

Cardiac output measured by transthoracic impedance cardiography at rest, during exercise and at various lung volumes. Edmunds AT, Godfrey S, Tooley M. Clinical Science 63, (107–113), 1982

Clinical evaluation of impedance cardiography. D. S. Goldstein, R. O. Cannon III, R. Zimlichman, H. R. Keiser.

PUBLICATIONS LIST

	Title.	Author.	Publication.	Product.
_1989	Electrode pad size, transthoracic impedance and success of external ventricular defibrillation	Dalzell GW, Cunningham SR, Anderson J, et al	Am J Cardiol 64:741–744 Oct 1989	PAD 300P/500P
_1997	Low-Energy Impedance-Compensating Biphasic Waveforms Terminate Ventricular Fibrillation at High Rates in Victims of Out-of-Hospital Cardiac Arrest	J Poole, R White, K-G Kanz, Friederike Hengstenberg, G Truett Jarrard	JCE Vol 8; 12, 1373 - 1385	PAD 300P/500P
_1998	Treatment of out-of-hospital cardiac arrest with a low-energy impedance-compensating biphasic waveform automatic external defibrillator	Gliner BE, Jorgenson DB, Poole JE et al	Biomed Instrum Technol. 32(6):631-44.	PAD 300P/500P
_1999	Comparison of a Novel Rectilinear Biphasic Waveform With a Damped Sine Wave Monophasic Waveform for Transthoracic Ventricular Defibrillation	Suneet Mittal, Shervin Ayati, Kenneth M. Stein	J Am Coll Cardiol. Vol. 34, No. 5	PAD 300P/500P
_1999	The Effects of Biphasic and Conventional Monophasic Defibrillation on Postresuscitation Myocardial Function	Wanchun Tang, Max Harry Weil, Shijie Sun, Hitoshi Yamaguchi, Heitor P. Povoas, Andreja Marn Pernat, Joe Bisera,	J Am Coll Cardiol. Vol. 34, No. 3	PAD 300P/500P
_1999	Rounded Biphasic Waveform Lowers Threshold for Transthoracic Ventricular Defibrillation	B J Kidwai, J D Allen, A McIntyre, J Anderson, A A J Adgey	PACE 2 (4:II), 872	PAD 300P/500P
_2000	Multicenter, Randomized, Controlled Trial of 150-J Biphasic Shocks Compared With 200- to 360-J Monophasic Shocks in the Resuscitation of Out-of-Hospital Cardiac Arrest Victims	Schneider T, Martens PR, Paschen H	Circulation 2000; 102:1780 –7	PAD 300P/500P

Title.	Author.	Publication.	Product.	
Transthoracic monophasic and biphasic defibrillation in a swine model: a comparison of efficacy, ST segment changes, and postshock hemodynamics	James T. Niemann, Daniel Burian, Daniel Garner, Roger J. Lewis	Resuscitation. 47; 51-58	PAD 300P/500P	_2000
Biphasic shocks are superior to monophasic for human transthoracic defibrillation	S. C. Faddy, J. Powell, J. C. Craig	Heart, Lung and Circulation. 9; 3; A148	PAD 300P/500P	_2000
Optimization of rounded biphasic waveforms to reduce threshold for transthoracic ventricular defibrillation.	Kidwai B, Allen D, McIntyre A, Anderson J, Adgey J.	Pacing Clin Electrophysiol, 23, 745	PAD 300P/500P	_2000
Patient outcomes following defibrillation with a low energy biphasic truncated exponential waveform in out-of-hospital cardiac arrest	Roger D. White, Daniel G. Hankins and Elizabeth J. Atkinson	Resuscitation. 49; 9-14	PAD 300P/500P	_2001
Optimization of transthoracic ventricular defibrillation-biphasic and triphasic shocks, waveform rounding, and synchronized shock delivery	Bakhtiar J. Kidwai, Allister McIntyre, John Anderson, A.A.Jennifer Adgey	JEC. Volume 35, Issue 3, Pages 235-244	PAD 300P/500P	_2002
A prospective, randomised and blinded comparison of first shock success of monophasic and biphasic waveforms in out-of-hospital cardiac arrest	Anouk van Alem, Fred W. Chapman, Paula Lank, Augustinus A.M. Hart	Resuscitation 58 17-24	PAD 300P/500P	_2003
Biphasic and monophasic shocks for transthoracic defibrillation: a meta analysis of randomised controlled trials	Steven C. Faddy, Jane Powell, Jonathan C. Craig	Resuscitation 58 9-16	PAD 300P/500P	_2003
Do clinically relevant transthoracic defibrillation energies cause myocardial damage and dysfunction?	Charles D. Deakin, Jonathan J.S. Ambler	Resuscitation 59 59-70	PAD 300P/500P	_2003

BIPHASIC DEFIBRILLATION STUDIES

	Title.	Author.	Publication.	Product.
_2004	Efficacy of Distinct Energy Delivery Protocols Comparing Two Biphasic Defibrillators for Cardiac Arrest	Walsh SJ, McClelland AJJ, Owens CG, Allen J, Anderson J McC., Turner C, A.A. Jennifer Adgey	Am J Cardiol. 94:378–380	PAD 300P/500P
_2004	Multicenter Study of Safety and Efficacy of a Biphasic Impedance-Compensating Waveform for Transthoracic Defibrillation	Randall Fincke, Charles I. Haffajee, David M. Barash, Francesco Fedele, Henry R. Halperin	J Am Coll Cardiol.43, Supp. 2; A299-A300	PAD 300P/500P
_2006	Post-shock myocardial stunning: A prospective randomised double-blind comparison of monophasic and biphasic waveforms	Charles D. Deakin, Jonathan J.S. Ambler	Resuscitation 68, 329-333	PAD 300P/500P
_2006	Transthoracic Incremental Monophasic Versus Biphasic Defibrillation by Emergency Responders (TIMBER)	Kudenchuk et al.	Circulation. 114, 2010-2018	PAD 300P/500P
_2006	A randomised controlled trial of efficacy and ST change following use of the Welch-Allyn MRL PIC biphasic waveform versus damped sine monophasic waveform for external DC cardioversion	Ambler JJS, Deakin CD	Resuscitation. 71: 146-151	PAD 300P/500P
_2007	A novel low-tilt biphasic waveform is efficacious with significantly lower voltage and current than a standard waveform in the defibrillation of VF	Darragh KM, Doyle C, Walsh SJ, Allen JD, Adgey AAJ, Anderson J, Manoharan G	Journal of Electrocardiology 40; S30–S36	PDU 400
_2009	A novel low tilt waveform for the defibrillation of ventricular arrhythmias during cardiac arrest	Darragh KM, Bennett JR, Manoharan G, Walsh SJ, Di Maio R, Allen JD, Anderson JMCC, Adgey AAJ	Europace (2009) 11 (suppl 2)	PDU 400
_2009	Superiority of Biphasic over Monphasic defibrillation shocks is attributable to less intracellular calcium transient heterogeneity	Gyo-Seung Hawng, Liang Tang, Boyoung Joung	J Am Coll Cardiol. Vol. 52; 828-835.	PAD 300P/500P

PUBLIC ACCESS DEFIBRILLATION

Title.	Author.	Publication.	Product.	
Public Locations of Cardiac Arrest Implications for Public Access Defibrillation	L Becker, M Eisenberg et al	Circulation. 97, 2106-2109.	PAD 300P/500P	_1998
Potential Cost-effectiveness of Public Access Defibrillation in the United States	G Nichol, A Hallstrom et al	Circulation. 97, 1315-1320	PAD 300P/500P	_1998
Public-access defibrillation	J Ornatoa, D Hankins et al	Prehosp Emerg Care. Vol. 3, 297 - 302	PAD 300P/500P	_1999
Public-access defibrillation: Where do we place the aeds?	M Gratton, D Lindholm et al	Prehosp Emerg Care, Vol. 3, 303 - 305	PAD 300P/500P	_1999
Technologic advances and program initiatives in public access defibrillation using automated external defibrillators	White, R	Curr Opin in Crit Care. Vol. 7, 145-151	PAD 300P/500P	_2001
Public access defibrillation in Helsinki: costs and potential benefits from a community-based pilot study	M Kuisma, M Castrén, K Nurminen	Resuscitation. Vol. 56, 149-152	PAD 300P/500P	_2003
Public-access defibrillation and survival after out-of-hospital cardiac arrest.	Hallstrom AP, Ornato JP et al	N Engl J Med. Vol.12, 637-46.	PAD 300P/500P	_2004
Public Access Defibrillation in Out-of-Hospital Cardiac Arrest A Community-Based Study	L Culley, T Rea, J Murray et al	Circulation. Vol. 109, 1859-1863	PAD 300P/500P	_2004
Results from Austria's nationwide public access defibrillation (ANPAD) programme collected over 2 years	R Fleischhackl, B Roessler et al	Resuscitation. Vol. 77, 195-200	PAD 300P/500P	_2008
A national scheme for public access defibrillation in England and Wales: Early results	M Colquhoun, D Chamberlain et al	Resuscitation. Vol. 78, 275-280	PAD 300P/500P	_2008
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SMART DEFIBRILLATOR

	Title.	Author.	Publication.	Product.
_1984	Improved neurologic recovery and survival after early defibrillation	WD Weaver, MK Copass, D Bufi, R Ray, AP Hallstrom	Circulation Vol. 69, 943-948	Smart Defib
_1984	Prehospital defibrillation performed by emergency medical technicians in rural communities	KR Stults, DD Brown, VL Schug, and JA Bean	NEJM. Vol. 310:219-223	Smart Defib
_1991	A Statewide Early Defibrillation Initiative Including Laypersons and Outcome Reporting	B Haynes, Mendoza, M McNeil, J Schroeder	JAMA. 1991;266(4) : 545-547.	Smart Defib
_1994	Early defibrillation by EMTs: the Brussels experience	P Mols, E Beaucarne, J Bruyninx, J Labruyere	Resuscitation. Vol. 27, Issue 2, 129-136	Smart Defib
_1997	Effects of Early Defibrillation by Ambulance Personnel on Short- and Long-term Outcome of Cardiac Arrest Survival	K Ladwig, R Danner, A Schoefinius, R Gürtler	CHEST. Vol. 112 no. 6 1584-1591	Smart Defib
_2001	Improving Survival From Sudden Cardiac Arrest	J Marenco, P Wang, M Link, M Homoud, M Estes III	JAMA. 285:1193-1200	Smart Defib
_2002	Resuscitation After Cardiac Arrest: A 3-Phase Time-Sensitive Model	M Weisfeldt, L Becker	JAMA. 288:3035-3038.	Smart Defib
_2009	Comparison of neurological outcomes following witnessed out-of-hospital ventricular fibrillation defibrillated with either biphasic or monophasic automated external defibrillators	Kajino et al.	Emerg. Med. J. 26:492-496.	Smart Defib
_2009	Preshock Cardiopulmonary Resuscitation Worsens Outcome From Circulatory Phase Ventricular Fibrillation With Acute Coronary Artery Obstruction in Swine	Indik et al.	Circ Arrhythm Electrophysiol. 2:179-184.	Smart Defib
_2010	A Randomized Controlled Trial of the Effect of Automated External Defibrillator Cardiopulmonary Resuscitation Protocol on Outcome From Out-of-Hospital Cardiac Arrest	Jost et al.	Circulation; 121:1614-1622.	Smart Defib

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Bystander-Initiated Cardiopulmonary Resuscitation in the Management of Ventricular Fibrillation	R Thompson, A Hallstrom, L Cobb	AIM. 90, 737-740	PAD 500P	_1979
Mechanisms of Blood Flow During Cardiopulmonary Resuscitation	M Rudikoff; W Maugha, M Effron, P Freund, M Weisfeldt	SOA. Vol.25, Issue 2	PAD 500P	_1981
Survival of out-of-hospital cardiac arrest with early initiation of cardiopulmonary resuscitation	R Cummins, M Eisenberg, A Hallstrom, Paul E. Litwin	The Am J of Emerg Med. Vol. 3, 114-119	PAD 500P	_1985
Prehospital Cardiopulmonary Resuscitation	R Cummins, M Eisenberg	JAMA. 253, 2408-2412.	PAD 500P	_1985
Bystander cardiopulmonary resuscitation (CPR) in out-of-hospital cardiac arrest. The Cerebral Resuscitation Study Group	Bossaert and Van Hoeyweghen et al.	Resuscitation. 17 Suppl:S55-69	PAD 500P	_1989
The effect of bystander CPR on neurologic outcome in survivors of prehospital cardiac arrests	http://www.ncbi.nlm.nih.gov	Resuscitation. 17, 1, 91-98	PAD 500P	_1989
Quality and efficiency of bystander CPR. Belgian Cerebral Resuscitation Study Group	Van Hoeyweghen RJ, Bossaert LL et al.	Resuscitation. 26(1):47-52.	PAD 500P	_1993
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_1997	Quality of mechanical, manual standard and active compression / decompression CPR on the arrest site and during transport in a manikin model	K Sunde, Lars Wik, P Steen	Resuscitation. Vol.34, 235-242	PAD 500P
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_2000	Cardiopulmonary Resuscitation by Chest Compression Alone or with Mouth-to-Mouth Ventilation	A Hallstrom, L Cobb, E Johnson, and M Copass	NEJM. 342, 1546-1553	PAD 500P
_2000	Effect of bystander cardiopulmonary resuscitation in out-of-hospital cardiac arrest patients in Sweden	Mikael Holmberg, Stig Holmberg, Johan Herlitz	Resuscitation. 47, 59–70	PAD 500P
_2003	Rediscovering the importance of chest compressions to improve the outcome from cardiac arrest.	L Wik	Resuscitation. 58, 267-9.	PAD 500P
_2003	Evaluation of a defibrillator-basic cardiopulmonary resuscitation programme for non medical personnel	Lars Wik, Elizabeth Dorph, Bjørn Auestad, Petter Andreas Steen	Resuscitation. 56, 167-172	PAD 500P
_2003	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. 58(3):249-58	PAD 500P

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_2008	Quality of cardiopulmonary resuscitation before and during transport in out-of-hospital cardiac arrest	T Olasveengena, L Wik, P Steen	Resuscitation. 76, 185—190	PAD 500P
_2008	Minimally Interrupted Cardiac Resuscitation by Emergency Medical Services or Out-of-Hospital Cardiac Arrest	Bobrow et al.	JAMA. 299, 1158-1165.	PAD 500P
_2009	Defibrillation and the quality of layperson cardiopulmonary resuscitation: Dispatcher assistance or training?	H Harvea, J Jokela, A Tissari, A Saukko, T Okkolin, V Pettilä, T Silfvast	Resuscitation. 80, 275–277	PAD 500P
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_1991	Reliability of impedance cardiography in measuring central haemodynamics	J. Mehlsen, J. Bonde, C. Stadeager, M. Rehling, M. Tangø, J. Trap-Jensen	Clin Phys and Func Imag. Vol 11 Issue 6, pp 579 - 588	PAD 500P
_1993	Detection of Shockable Ventricular Tachyarrhythmias Using Transthoracic Impedance Cardiography	P W Johnston, J D Allen, G J Dempsey, J Jossinet, Z Imam, J Anderson, A A J Adgey	European Heart Journal: XVth Congress of the European Society of Cardiology, Vol 14, 2330, August, 1993	PAD 500P
_1993	Use of the Transthoracic Impedance Cardiogram as a Haemodynamic Indicator in Ventricular Tachyarrhythmias	P W Johnston, D Allen, G J Dempsey, J Jossinet, J Anderson, A A J Adgey, Z Imam	Pacing and Clinical Electrophysiology, 16, 5 p1162-1166	PAD 500P
_1994	Detection of Shockable Ventricular Tachycardia by Impedance Cardiography using 2 ECG/Defibrillator Pads	P W Johnston, J D Allen, G Dempsey, J Jossinet, Z Imam, J Anderson, A A J Adgey	Irish Journal of Medical Science, 163, 398	PAD 500P
_1995	The Potential Use of Impedance Cardiography as a Haemodynamic Sensor for Automated External Defibrillators	P W Johnston, J Anderson, A A J Adgey	Irish Journal of Medical Science 164, p.69-73	PAD 500P
_1998	The transthoracic impedance cardiogram is a potential haemodynamic sensor for an automated external defibrillator	Johnston PW, Imam Z, Dempsey G, Anderson J, Adgey AAJ	European Heart J. 1998; 19 (12): 1879-1888	PAD500P
_1999	A meta-analysis of three decades of validating thoracic impedance cardiography	Raaijmakers E, Faes T, Scholten, Rob J, Goovaerts H, Heethaar R	Critical Care Medicine. Volume 27 - Issue 6 - pp 1203-1213	PAD 500P
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_2003	Impedance Cardiography	Joseph M. Van De Water, Timothy W. Miller et al	Chest vol. 123, 2028-2033	PAD 500P
_2004	Fast Fourier Transformation of the Impedance Cardiogram Recorded Through Two Defibrillator Pads is a Powerful Determinant of Cardiac Arrest in the Porcine Model	Cromie N, Allen JD, Moore M ,Glover B, Di Maio R, Allen J, Anderson JMCC, Adgey AAJ	Circulation. 110 suppl III – 342	PAD 500P

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The Impedance Cardiogram recorded through the novel configuration of two defibrillator/electrocardiogram pads provides a powerful determinant of cardiac arrest	Cromie NA., Allen J., Anderson J., Adgey A	Heart, vol. 92(Supplement II):A4–A121	PAD 500P	_2006
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The use of impedance cardiography in automatic external defibrillators to discriminate between shockable and nonshockable ventricular tachycardia in real time	Di Maio R, Navarro C., Cromie N.A., Anderson J.M.C, Adgey A.A.J	Journal of Electrocardiology 4: 609	PAD 500P	_2009
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The Impedance Cardiogram is an indicator of CPR effectiveness for out-of-hospital cardiac arrest victims	Rebecca C. Di Maio, Cesar Navarro, Nicholas Cromie, John McC Anderson, Jeniffer AJ Adgey	J Am Coll Cardio, Vol 55, Issue 10, Supp 1, Page A217	PAD 500P	_2010
Impedance Cardiogram to measure CPR efficacy and rate for out-of-hospital cardiac arrest victims. Breakout Presentation	Di Maio R, Navarro C, Cromie NA, Anderson J MCC, Adgey AAJ	TBA (Accepted European Society of Cardiology)	PAD 500P	_2010

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