Cardio Compression Control Device: Development, Calibration and Testing

Irena Jekova[1,*], Vessela Krasteva[1], Tatyana Neycheva[1], Nikolay Mudrov[1], Zhecho Kostov[1], Jean-Philippe Didon[2]

[1]*Centre of Biomedical Engineering, Bulgarian Academy of Sciences*
105 Acad. G. Bonchev Str., 1113 Sofia, Bulgaria
E-mail: irena@clbme.bas.bg, vessika@clbme.bas.bg, tatiana@clbme.bas.bg, mudrovn@clbme.bas.bg,

[2]*Schiller Médical SAS, 4 rue L. Pasteur, F-67160 Wissembourg, France*
E-mail: jean-philippe.didon@schiller.fr

[*] *Corresponding author*

Received: September 29, 2009 **Accepted: October 8, 2009**

Published: October 14, 2009

Abstract: *Cardio-pulmonary resuscitation (CPR) is a life-saving first aid which is part of the treatment given in case of sudden cardiac death. According to the American Heart Association (AHA) 2005 Guidelines for CPR, there are three key components related to the chest compressions which should be considered: (i) optimal compression depth between 3.8 and 5.4 centimeters; (ii) optimal compression rate between 85 and 115 compressions per minute; (iii) complete chest recoil by releasing all pressure from the chest after each chest compression (CC).*
A device for automatic control of the quality of chest compressions during CPR was developed. It embedded hardware and software solutions for simultaneous measurement of the depth, rate and the chest recoil thus providing a feedback about the efficiency of the cardiac massage at each CC compression. The system is applicable as a training device for basic education in CPR or as a consulting system for rescuers on the scene of the cardiac incident. The accuracy of the CC Device was adjusted by theoretical and experimental calibration, and tested by planned experiments, as well as experiments with a medical team.

Keywords: *Chest compressions quality monitoring, CPR training device, Accelerometer.*

Introduction

Chest compressions (CC) are part of the cardio-pulmonary resuscitation (CPR) – a life-saving first aid, which is applied in case of sudden cardiac death. The chest compression has two phases – the active phase, when force is applied downward on the chest, and the passive phase, when pressure is released and the chest is allowed to recoil to its normal shape. During the active phase, the heart is squeezed between the sternum and the spine, compressing the ventricles and causing blood to be pumped out to the lungs and body. Venous blood returns to the heart during the passive phase, flowing through the atria and into the ventricles. During cardiac arrest, venous blood returns to the heart only if the intrathoracic pressure is less than the intra-abdominal pressure. This is critical to the effectiveness of CPR [5].

Performing qualitative CPR in the treatment of cardiac arrest may increase the patient's chance of survival and may improve the outcome for a complete neurological recovery [3]. The American Heart Association (AHA) 2005 Guidelines for CPR [1] state that methods should be developed to improve the quality of CPR delivered at the scene of cardiac arrest by healthcare providers and lay rescuers. Based on what is now known about the pathophysiology of the cardiac arrest, the physiology of CPR and the latest research, the AHA defines the requirements supporting the optimal metabolic environment for the heart so that defibrillation results in a return of spontaneous circulation. In the view of chest compression, there are 3 key components that should be considered:

- Optimal compression rate between 85 and 115 compressions per minute (cpm).
- Optimal compression depth between 3.8 -5.4 cm.
- Complete chest recoil during the passive phase by relieving all pressure from the chest.

The practice shows that the quality of CPR performed both in and out of the hospital, declines due to specific human errors:

- Interruption of the CPR too frequently to perform other tasks, resulting, in average, in less than 60 cpm being delivered.
- Not compressing the chest fast enough or deep enough, resulting in low coronary perfusion pressures.
- Due to poor technique and/or rescuer fatigue, the chest is not allowed to recoil completely, leading to higher intrathoracic pressures after compression (thus decreasing venous return).

Many studies on manikins report inadequate CPR performance and a need for improvement of the basic CPR skills of professional rescuers from the emergency medical services, paramedics and lay persons when a real-time audiovisual feedback system (e.g. Automated Voice Advisory Manikin System) is provided [2, 4, 6].

The CPR errors are supported by the key limitation of manual CPR, which appear to be the lack of controls or prompts to encourage rescuers to perform compressions at the correct rate and depth. The present work is aimed at overcoming the human factor during CPR by designing a system for monitoring the main CC quantities, i.e the compression rate, the compression depth and the chest recoil, and feeding back an indication about the efficiency of CCs. This system can be used for basic education in CPR, as well as on humans in cardiac arrest. It gives clear and easy apprehensible indications about the measured CC quantities and supports real-time transfer of all acquired and calculated data to a central processing unit (e.g. PC) for detailed monitoring of the cardiac massage process.

Hardware solution

The block diagram of the Cardio Compression Control device (CC device) is presented in Fig. 1. It includes a CC-POD (Pad for Optimal Depth) with compression sensors and a Display Unit.

The POD is equipped with a 3-axis accelerometer (ADXL330, Analog Devices) mounted on a printed circuit board parallel to the surface of the pad. Thus the whole assembly is designed to produce an acceleration signal on the accelerometer Z-axis output during the up-down movements related to the cardiac massage. Any parasitic horizontal movements could be detected by measurements along the accelerometer’s X and Y axes and the lifesaver could be warned in a feedback. The POD is equipped also with a force activated switch, mounted just beneath its flexible upper surface. The idea is that any vertically applied force is activating the switch, thus the lack of switch activation is a reliable feedback about the complete recoil of the chest.

The Display Unit embeds electronic circuits designed to provide the acquisition, the signal processing and the indications concerning continuous monitoring of the cardiac compressions quality. The autonomous operation of the Display Unit is controlled by PIC24HJ256GP206 microcontroller, which handles all operations related to data sampling and signal processing. All results are presented by a simple indication output, designed for easy apprehension by the human eye. Sets of light-emitting diodes (LEDs) are used to display independently the compression depth, rate and chest recoil. Green LEDs in each set indicate the normal ranges of depth, rate and the recoil. Such indications facilitate the lifesavers who have to keep only green lights blinking to be sure that the massage is performed correctly. The lighting of red LEDs is an instant visual warning for disturbance of the compression quality and the position of the red LED (weak depth, extreme depth, low rate, high rate, incomplete recoil) is just a simple feedback for the CC correction needed.

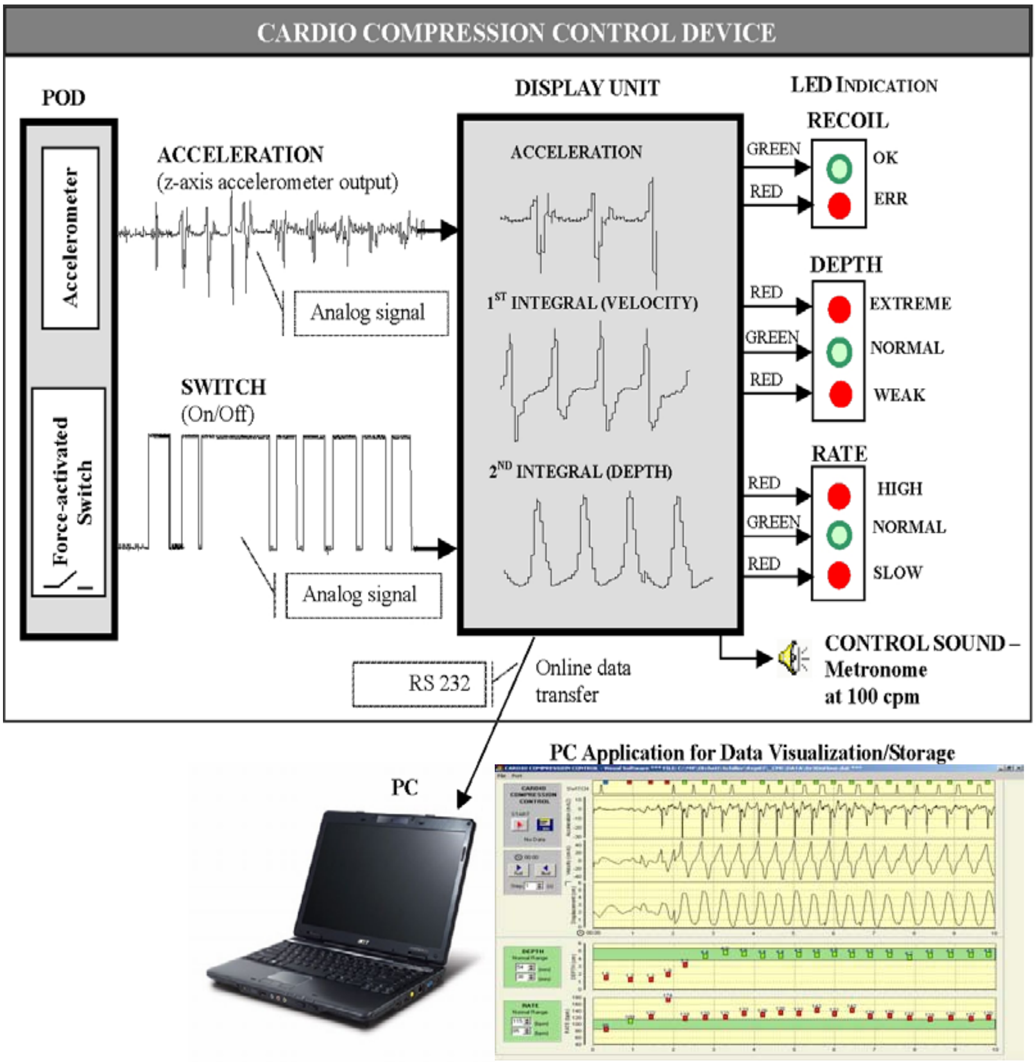


Fig. 1 Block diagram of the Cardio Compression Control device: The signals generated by the POD's compression sensors (accelerometer and force-activated switch) are processed in the Display Unit to produce adequate LED indication about the chest recoil, compression depth and rate. Online data transfer is provided for testing purposes including signals visualization and storage.

An assistant for the lifesavers is the build-in Metronome Control Sound. It is beating the time of compressions with an optimal rate of 100 cpm according to the recommendations.

The application of the designed prototype on a manikin is presented in Fig. 2. The POD has to be placed on the chest, therefore its shape is designed with an ergonomic consideration to fit best at the lower third of the sternum.

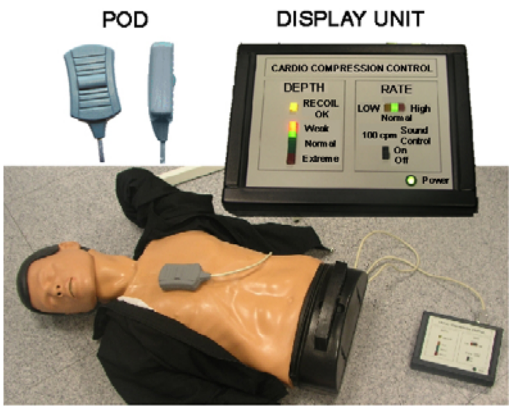


Fig. 2 Cardio Compression Control device used on a manikin. The POD with compression sensors is designed to fit at the sternum. The Display Unit is equipped with LEDs indicating the quality of the massage.

Signal processing

The signal processing consists of several steps:

Step 1: Detection of the CC cycles with period ***T*** [s] used for calculation of the CC rate (Equation 1):

$$CCrate = 60/T\,[cpm] \quad (1)$$

Step 2: Measurement of the compressions depth by fast algorithm for double integration over the acceleration samples *a* (Fig. 3, 1st trace) in one CC period *T*.

The first integration (Fig. 3, 2nd trace) calculates the velocity *v* for each consecutive sample *i*, according to Equation 2:

$$v_i = \Delta t \sum_{1}^{i} (a_i - a_{av}) \Big|_{i=1}^{n} \quad (2)$$

where Δt is the sampling period; $n=T/\Delta t$ is the number of the samples in *T*, a_{av} is the average acceleration in *T*.

The second integration (Fig. 3, 3rd trace) calculates the displacement *s* for each sample *i*, according to Equation 3:

$$s_i = \Delta t \sum_{1}^{i} (v_i - v_{av}) \Big|_{i=1}^{n} \quad (3)$$

where v_{av} is the average velocity in *T*.

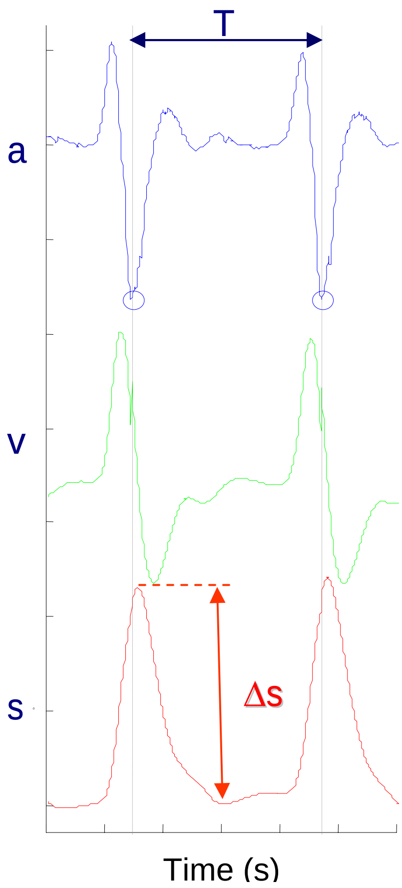


Fig. 3 Acceleration (a), velocity (v) and displacement (s)

The total depth of one full CC cycle is found by the peak-to-peak measure of *s* (Eq. 4):

$$\Delta s = [\max(s) - \min(s)] \quad (4)$$

Step 3: The signal from the force activated switch is checked between each two consecutive CC cycles. If the switch does not turn off, incomplete recoil is detected.

Theoretical Calibration

Transform coefficients are defined for conversion between the input of the system and the measured values. These are the transform coefficients for acceleration K_A, velocity K_V and displacement K_S. Their theoretical calculations are conformed to the particular system, including the accelerometer with its sensitivity A_{sens} [V/g] (g=9.81 m·sec^{-2} is the acceleration of gravity), the input gain control defined by a resistor divisor with a transmission coefficient K_R (K_R < 1) and the analogue-to-digital converter having sensitivity ADC_{sens} [V/sample]. The sampling frequency Fs is also involved in the calculation of the transform coefficients, as follows:

$$K_A = \frac{ADC_{sens}}{K_R * A_{sens}} * 100\,,\ [\text{cm·s}^{-2}] \tag{5}$$

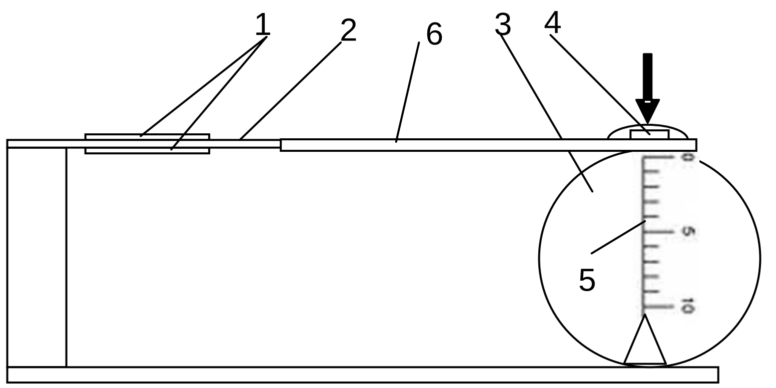
$$K_V = \frac{ADC_{sens}}{K_R * A_{sens} * Fs} * 100\,,\ [\text{cm·s}^{-1}] \tag{6}$$

$$K_S = \frac{ADC_{sens}}{K_R * A_{sens} * Fs^2} * 100\,,\ [\text{cm}] \tag{7}$$

Experimental Calibration on a Test Bench

A test bench is created for reference measurements of the real displacement of the POD in a controlled experiment. The aim is to compare the reference displacement to the accelerometer measurements, thus proving both the principle of double integration and the calibration of the transform coefficient K_S.

The reference measurement system is based on tensoresistors with a preset sensitivity [V/cm]. Its construction is quite simple as shown in Fig. 4, assembled by: (1) tensoresistors (X3-300), connected to an amplifier through unbalanced strain-gauge measuring bridge; (2) elastic bar; (3) mechanically resistive element; (4) POD with accelerometer, mounted at the free bar end.



1 – tensoresistors
2 – elastic bar
3 – mechanically resistive element (ball)
4 – POD with accelerometer
5 – Ruler for the depth of the compressions

Fig. 4 Experimental setting for reference displacement measurement

The principle for experimental calibration is set as follows: The POD with accelerometer (4), mounded at the free solid bar end (6) is pressed. Then the elastic bar (2) bends, and the tensoresistors (1) generate a voltage signal proportional to the shifting of the solid bar end. In order to simulate movements of the accelerometer, similar to the CPR compressions, the free bar end is manually moved downwards and upwards in a periodical manner (at about 80 to 120 compressions-per-minute) to a desired depth (read from the ruler, at about 3.8 to 5.4 cm).

The simultaneous recordings of both the tensoresistors' output and the accelerometer's output are used to directly compare the waveforms of the reference displacement and the displacement calculated by the CC device. Such example is shown in Fig. 5.
The top subplot represents: (1) the displacement calculated as the second integration of the acceleration (the red curve); (2) the tensoresistors' output used as the reference displacement (the black curve). The fitting of the two waveforms confirms the correct principle of integration applied on the acceleration, and the equivalence of their ranges proves the appropriate calculation of the theoretically derived K_S coefficient (used to scale the accelerator's displacement signal).

The bottom subplot illustrates the total displacement derived by the peak-to-peak amplitude of each cycle between the bottom dead point and the top dead point of the up-down and down-up movement: (1) the amplitude of the accelerator's displacement (the red asterisks); (2) the reference amplitude of the tensoresistors' output (the black circles). The coincidence between asterisks and circles on the y-scale confirms the proper calculation of the movement depth (in cm).

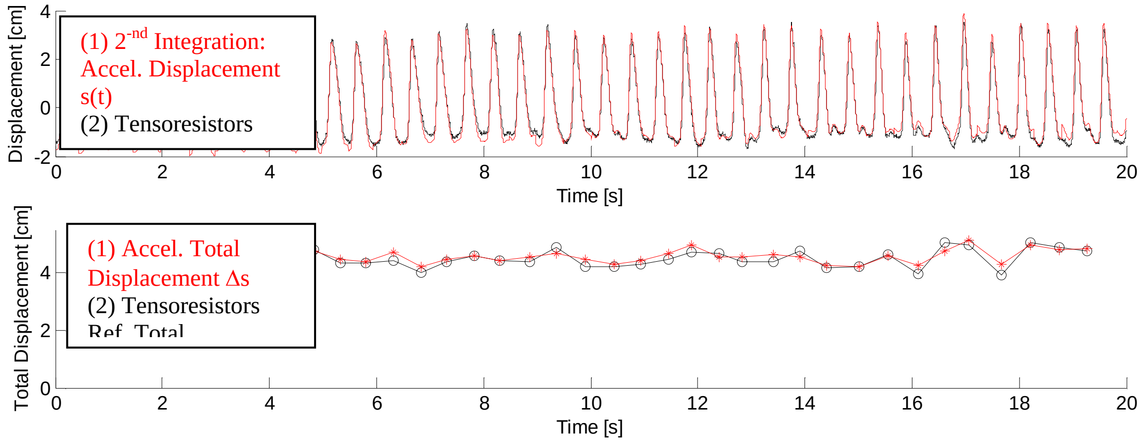


Fig. 5 Experimental results for calculated and reference displacements

Controlled Experiments on a Manikin

The correct work of the CC device is verified with a set of experiments on a manikin. The indications of the CC device are compared to the manikin's reference indications about rate and depth of the chest compressions.

A real experiment in Fig. 6 depicts four simultaneous signals: switch output, acceleration, velocity and displacement, as recorded and calculated by the CC device during series of chest compressions with and without recoil performed by keeping relatively equal bottom depth position.

- **State 1**: the chest is in its initial position (named also Top Dead Center or Zero level) – the switch is OFF, the acceleration is zero.
- **State 2**: the chest is pressed slowly down until the switch turns ON; the acceleration still remains at about zero.
- **State 3**: a series of three chest compressions with recoil between Zero level and level A1 (about 4-6 cm in depth). The peak-to-peak amplitude of the calculated displacement corresponds to this depth. The switch was also activated three times as the number of compressions. The switch activation phases are described in Fig. 7.
- **State 4**: a series of four chest compressions without recoil between level A2 (1-2 cm in depth) and level A1 (4-6 cm in depth). The peak-to-peak amplitude of the displacement is

reduced compared to State 3, correctly measured to be about 4 cm. The switch is permanently turned ON, which is the indication for incomplete recoil.

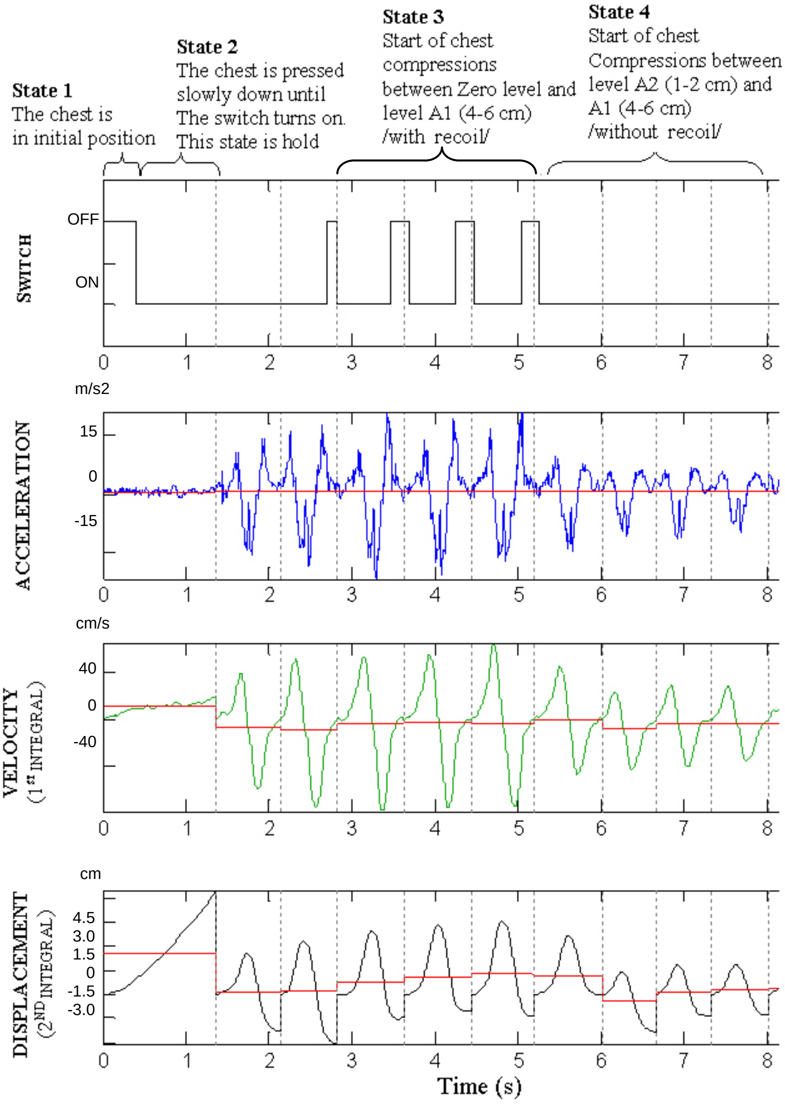


Fig. 6 Series of compressions with and without recoil performed by keeping relatively equal bottom depth position A1 (4-6 cm). The measured amplitude of the compressions with and without recoil is different.

The correct operation of the switch is confirmed by detailed analysis of the switch output. Fig. 7 presents the switch signal superimposed with both the acceleration and the calculated displacement. This illustration confirms that:

(1) the switch turns from OFF to ON state just after the beginning of the up-down movement, identified from the first fast rising front of the acceleration and the displacement near to its minimum;

(2) the switch keeps its ON state during the active phase, identified by the rapid change of the acceleration during the up-down and the down-up movement. This concurs with the rising and the falling phase of the displacement, corresponding to the gradual chest concavity and the gradual chest release during the compression;

(3) the switch turns from ON to OFF state just after the chest is almost fully released during the final phase of the down-up movement, identified from the slowing down front of the acceleration, and from the displacement near to its minimum.

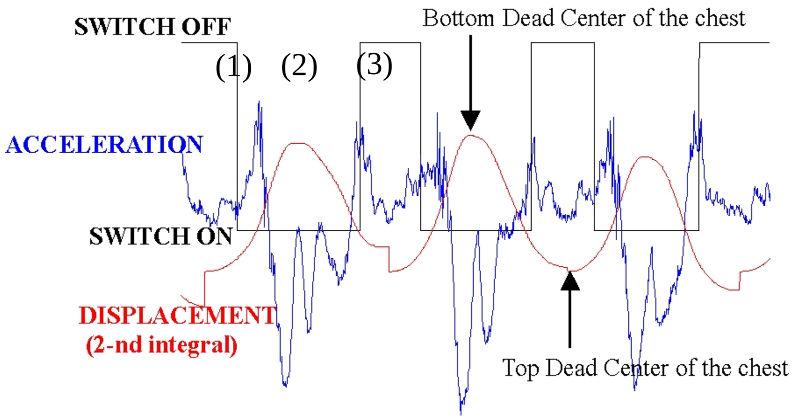


Fig. 7 Switch output, acceleration and displacement signals

Experiments with a Medical Team

Initial in-hospital testing of the CC device is done in the Coronary Care Unit of the National Heart Hospital, Sofia, Bulgaria. Twelve members of the medical team, working in the unit but not trained in basic CPR skills, are asked to perform CC on a manikin by using the prototype of the CC device. The prototype is applied in the same way as it should be used for training of first responders. The manikin is placed on the floor. The POD is put on the chest of the manikin, and the Display Unit provides: (i) LED indication as a feedback of the compressions depth, rate and recoil; (ii) metronome sound to beat the compressions rhythm. The operation of the CC device is observed in real-time on PC supported by in-house developed software for data transfer, visualization and data storage. Examples of the application window during the training process are illustrated in Fig. 8 to Fig. 11. The following signals are depicted from top to bottom: the switch state (on/off), acceleration (m/s^2), velocity (cm/s), displacement (cm), depth (cm) calculated as the peak-to-peak amplitude of the displacement for each CPR cycle, rate (cpm) calculated as the frequency (period) of each consecutive CC compression.

The aim of the study is to verify the ability of the medical team to get trained with the CC device. An experimental protocol is defined with a training process of maximum 3 minutes. During the training process the volunteer follows the LED indications for depth, rate and recoil and listens to the metronome control sound at 100 cpm. If the participant succeeds to maintain adequate chest compressions for at least 10 seconds he/she is asked to stop.

Fig.8a shows the signals and the indications recorded during the first attempt of a volunteer to perform CC on a manikin. This is a typical example of how the CC device works as a feedback guide for the compression corrections needed. The participant started with correct chest recoil and adequate compression depth but with too rapid rate. After a warning from the device, he slowed down the compression rate but at the same time he decreased the compressions depth, as well as some incomplete recoils occurred. After a training period of 35 seconds (Fig. 8b), the same participant succeeded to maintain periodical chest compressions over time with a rate corresponding to that of the metronome, depth within the range of the 'green zone' and recoil 'OK' at the end of each CC.

The second example (Fig. 9a) shows the attempt of other participant who succeeds very fast to get trained in making recoil and sufficient depth (only after 5 compressions) but holding fast CC rate (> 120 cpm). Just after 12 seconds (Fig. 9b) this participant succeeds to correct the CC rate about 100 cpm thus complying with all requirements for correct CC massage.

Fig. 10a shows the beginning of the CC trial of other participant who starts with correct recoil and depth (between 4.2 cm and 5 cm), but with sustained slower CC rate (about 70 cpm). After 31 seconds (Fig.10b) this participant has been trained to increase the CC rate up to the normal levels at about 90 cpm.

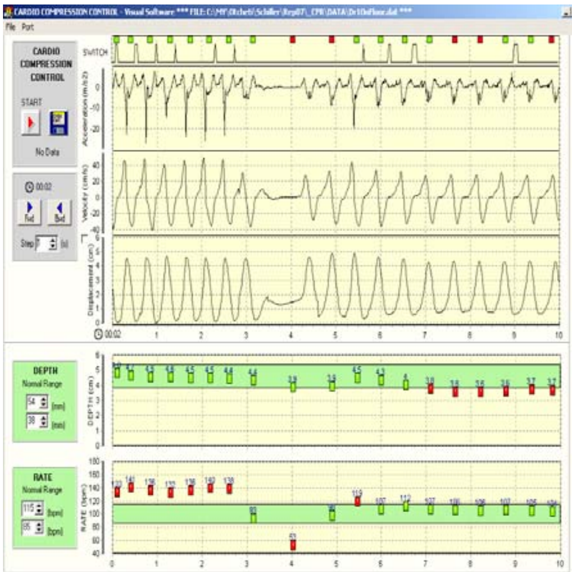


Fig. 8a First attempt of a volunteer for CPR on a manikin: Start with problematic high CC rate (~135 cpm). When trying to adjust the CC rate, the CC depth decreased below the limit (<3.8 cm). Problems with the recoil are also observed.

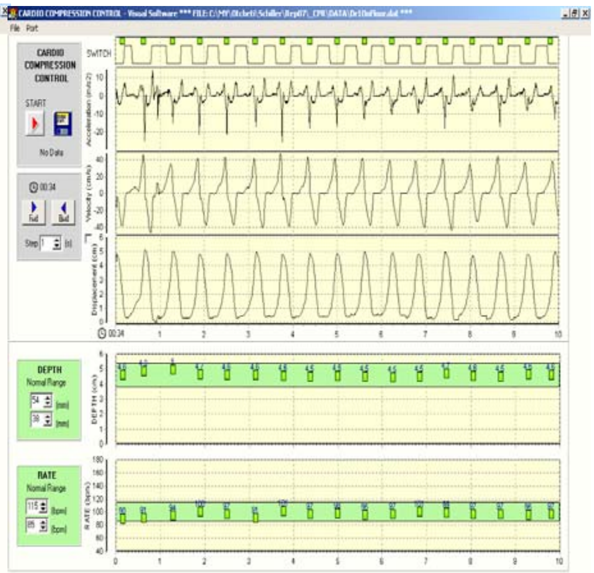


Fig. 8b After training, the same volunteer succeeds to provide CPR massage with stable movements, which satisfy the requirements for correct CC rate, depth and recoil. He has been trained to control the strength and rate of the compressions during the massage.

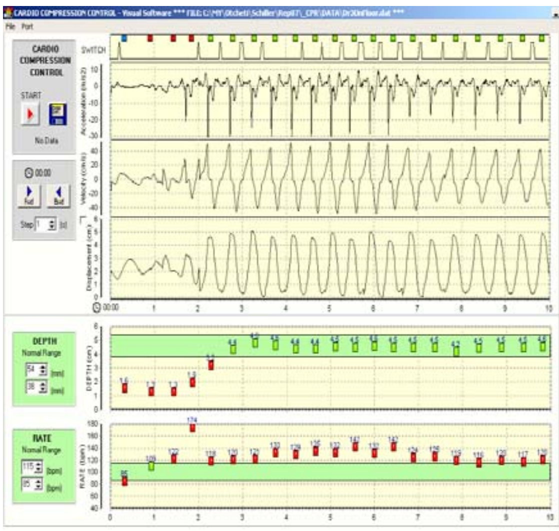


Fig. 9a The beginning of the CPR attempt of a volunteer. Start with: (i) incomplete recoil, corrected to perform recoil just after the 3rd compression; (ii) smaller CC depth (1.5 cm), corrected to the normal levels (~ 4.5 cm) just after the 5th compression; (iii) higher than the normal CC rate (118-142 cpm).

Fig. 9b At the end of the CPR attempt, the same volunteer succeeds to slow down the CPR rate, and thus to provide CPR massage with stable movements, satisfying the requirements for correct rate, depth and recoil. He has been trained to control the strength and rate of the compressions during the massage.

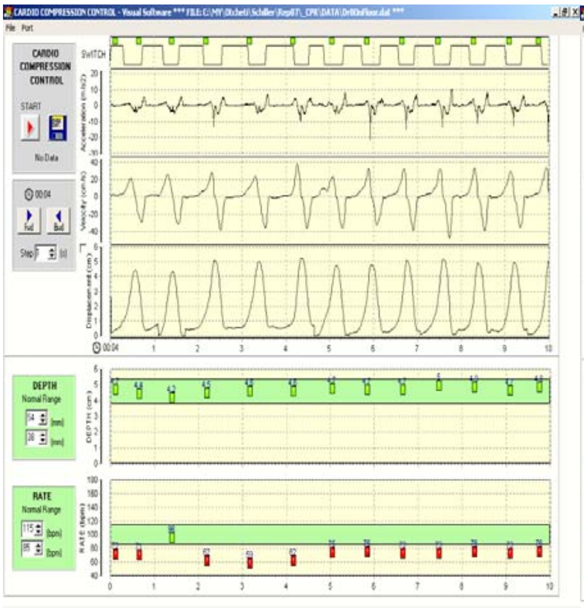


Fig. 10a The beginning of the CPR attempt of a volunteer. Start with slow CC rate (~ 70 cpm). No problems with the recoil. The depth of the compressions is adequate and stable (~ 4.2 cm).

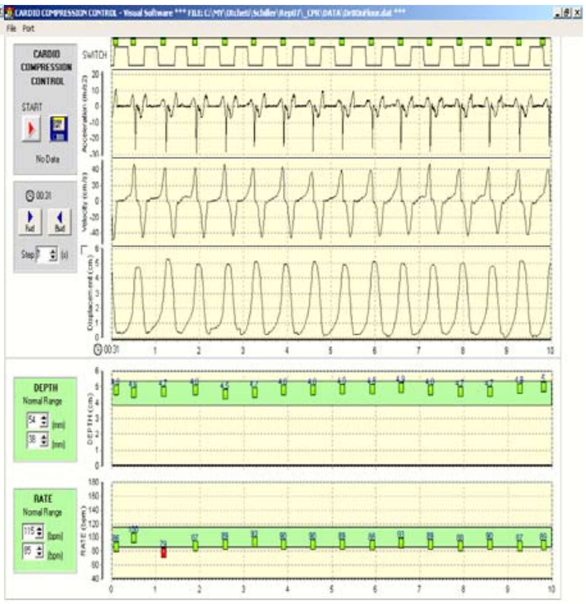


Fig. 10b At the end of the CPR attempt, the same volunteer succeeds to perform massage with correct CC rate (~90 cpm). He has been trained to provide CPR massage, satisfying the requirements for correct CPR rate, depth and recoil.

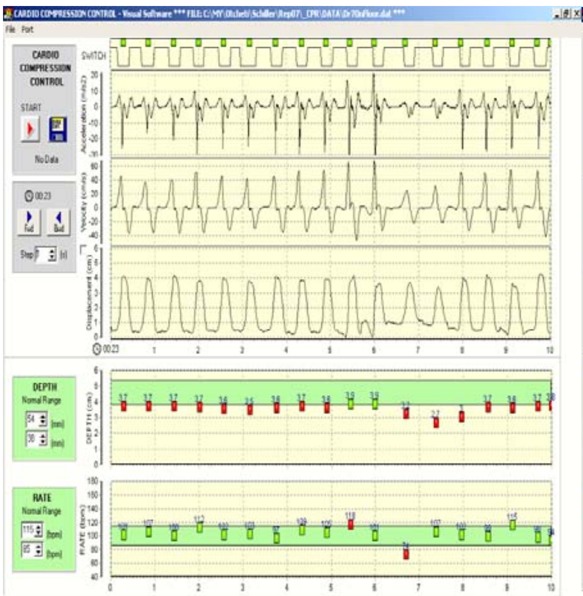


Fig. 11a The beginning of the CPR attempt of a volunteer. Start with small CC depth (between 2.5 and 3.7 cm). The CC rate is normal (~ 100 cpm) but with transitory failures. No problems with the recoil.

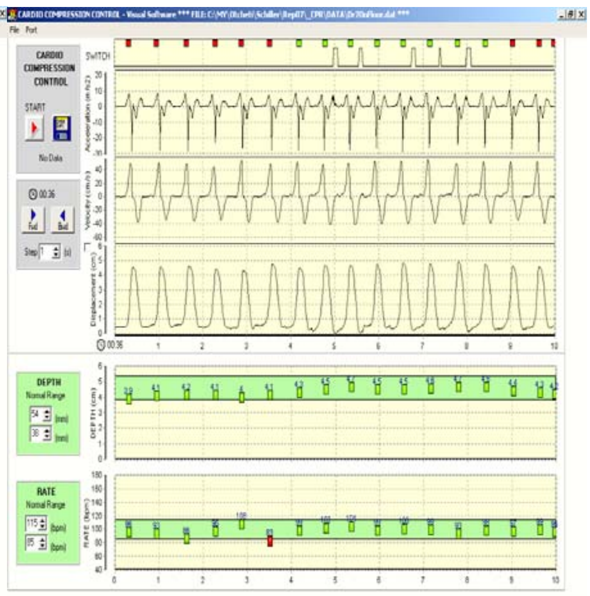


Fig. 11b After training, the same volunteer succeeds to provide CPR massage with correct CC rate and depth. The observed problems with the recoil are probably due to fatigue.

The participant in Fig. 11a maintains CC at small depth. An attempt to increase the depth results in a transient swing of the CC rate. After 36 seconds of training (Fig. 11b) this participant maintains CC at normal rate and depth, although there appear a sequence of CC periods with incomplete recoil probably due to human fatigue.

Table 1 summarizes the abilities of all participants in the experiment to perform CC massage on a manikin before and after training with the CC device.

Table 1. Classification of the CC attempts of all 12 participants according to the achieved depth (Low, Normal, Extreme), rate (Slow, Normal, Rapid) and recoil (OK, ERR) measured before and after training.

Parameter	Indication	First CPR attempt	CPR attempt after training
Depth	Low	58.3 % (7/12)	33.3 % (4/12)
	Normal	33.3 % (4/12)	66.7 % (8/12)
	Extreme	8.3 % (1/12)	0 % (0/12)
Rate	Slow	33.3 % (4/12)	0 % (0/12)
	Normal	33.3 % (4/12)	91.7 % (11/12)
	Rapid	33.3 % (4/12)	8.3 % (1/12)
Recoil	OK	75.0 % (9/12)	91.7 % (11/12)
	ERR	25.0 % (3/12)	8.3 % (1/12)

Discussion

The CC device was designed for real-time tracking of the movements during CPR, in order to obtain an immediate feedback about the quality of the massage just after each compression. The adequate construction of the moving part of the system in contact with the human body, i.e. the POD, allows to produce analogue signals (acceleration, output from the force-activated switch) correlated to the movements of the rescuer's hands and the patient's body during the CPR massage. The next module of the system, i.e. the Display Box, supports continuous acquisition and sampling of the analogue signals produced from the POD. The Display Box also makes all processing related to calculations of the chest displacement applying the principle of double integration of the acceleration over each CC cycle, as well as the detection of the recoil (by analysis of the switch output).

In this work we show the calibration of the system. In a first step theoretical transform coefficients for acceleration K_A, velocity K_V and displacement K_S are derived (Equations 5 to 7) taking into account the hardware specifications of the system. In a second step a test bench based on tensoresistors is constructed to provide reference measurements of the displacement. The comparison between the simultaneous recordings of the tensoresistors output and the 2nd integration of the acceleration (Fig. 5) proves their equivalence in waveform and in amplitude. This fact is used as a proof of the method for depth calculation from acceleration, i.e. the principle of double integration and the transform coefficients used to scale the depth in centimeters.

The system is first tested on a manikin in a series of compressions with controlled depth using the feedback reference indications embedded in the manikin. Over the presented experiment (Fig. 6), the amplitudes of acceleration, velocity and displacement decrease proportionally between the two series of compressions – the first series with about 6 cm in depth and the second series of about 3-4 cm in depth. The recoil detection is also tested in this experiment by observations over the switch output. The second series of compressions without return to the Zero level (State 4 in Fig. 6) confirms no switching to OFF state, which is the precondition for detection of incomplete recoil. The analysis of the switch output for the movement with return to zero level (Fig. 7) confirms the reliable activation of the switch during the CC active phase and its reliable deactivation near the Zero Level.

The real time transfer of the input/output data of the CC Device to PC is used as a control tool. Firstly, this control environment on the PC screen is used to trace the time course and the amplitudes of all signals – the switch output, the acceleration, the velocity and the displacement, the latter two as calculated by the embedded method. Second, the discrete numerical values displayed for the depth and the rate of each CC compression are used to verify the LED indications on the Display Box. Thus we verified that CC cycles with measured depth between 3.8 and 5.4 cm and measured rate between 85 and 115 cpm are indicated by the corresponding green LEDs, and any outlying values are indicated by red LEDs.

The last testing of the CC device is with a medical team including 12 volunteers who are instructed how to interpret the CC device LED indications and the metronome sound. The analysis of the recordings of their training process with the CC device allows us to make conclusions about the benefits of the training CC device. The presented examples (Fig. 8-11) illustrate different inabilities of the volunteers to perform CPR massage at the first trial. Three of the examples show absolutely correct CPR massage of the same volunteers who follow the CC device indications for no more than 35 seconds. The summary results involving all volunteers (Table 1) prove the need for such CC device since only about 30 % of the participants in the experiment succeed in performing chest compressions on a manikin within the ranges of normal depth and rate. After training to follow the feedback with green LED indications, 3 out of 7 cardiologists who have started with low depth of the chest compressions, as well as the one who has started with extreme depth, succeed to correct their massage within the normal levels. Nevertheless, 4 out of 7 participants, keep low depth of CC along the test. It seems that they do not have enough strength to maintain chest compressions with normal depth. When the participants are trained to keep normal compressions rate, they observe the LED indications and simultaneously listen to the control sound of the metronome with a rate of 100 cpm. This technique prove to be effective since only 1 out of 12 persons do not succeed to correct his movements to follow the nominal rate of 100 cpm. The indication for a recoil error help 2 out of 3 participants to release their hands from the chest after each compression.

In this study, we prove the ability of the designed CC device to measure adequately the chest compression quantities. By real-time audiovisual feedback for the quality of CC, the CPR skills of the trained persons are improved and they achieved and maintained correct CPR massage.

Acknowledgments

This study has been supported by Schiller AG.

References

1. American Heart Association 2005 Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Adult Basic Life Support., Circulation, 2005, Vol. 112, pp IV-29.

2. Aufderheide T., R. Pirrallo, D. Yannopoulos, J. Klein, C. von Briesen, C. Sparks, K. Deja, C. Conrad, D. Kitscha, T. Provo, K. Lurie (2005). Incomplete chest wall decompression: a clinical evaluation of CPR performance by EMS personnel and assessment of alternative manual chest compression-decompression techniques. Resuscitation, 64(3), 353-362.
3. Chow-In Ko P., W. Chen, C. Lin, M. Huei-Ming Ma, F. Lin (2005). Evaluating the quality of prehospital cardiopulmonary resuscitation by reviewing automated external defibrillator records and survival for out-of-hospital witnessed arrests. Resuscitation, 64, 163-169.
4. Park D., G. Cho, J. Ryu, J. You, D. Oh (2008). The Effect of a Real Time Audiovisual Feedback System on the Quality of Chest Compressions by Trained Personnel during Resuscitation: A Randomized Controlled Trial using a Manikin Model., J Korean Soc Emerg Med., 19(1), 37-44.
5. Wesley A.K. (2006). Improving the Hemodynamics of CPR. EMS Magazine, March 2006.
6. Wik L., J. Thowsen, P. Steen (2001). An Automated Voice Advisory Manikin System for Training in Basic Life Support Without an Instructor. A Novel Approach to CPR Training. Resuscitation, 50, 167-172.

Assoc. Prof. Irena Jekova, Ph.D.
E-mail: irena@clbme.bas.bg

Irena Jekova graduated Technical University - Sofia, Faculty of Electronic Engineering and Technology, specialization Electronic Medical Equipment in 1998. She has been working in the Centre of Biomedical Engineering, Bulgarian Academy of Sciences since 1999. She defended her Ph.D. thesis in the field of ventricular fibrillation detection in 2001. In 2007 she became Associate Professor. I. Jekova was awarded as a young scientist by the Bulgarian Academy of Sciences (2002) and by the Union of Scientists in Bulgaria (2007) for her outstanding scientific achievements in the development of methods and algorithms for ECG signal processing. Her scientific interests are in the field of biomedical signals and data processing, ECG analysis and arrhythmia classification.

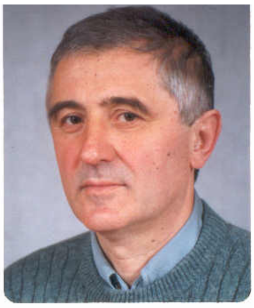
Assoc. Prof. Vessela Krasteva, Ph.D.
E-mail: vessika@clbme.bas.bg

Vessela Krasteva graduated Technical University - Sofia, Faculty of Electronic Engineering and Technology, specialization Electronic Medical Equipment in 1998. Since 1999, she is working in the Centre of Biomedical Engineering, Bulgarian Academy of Sciences. In 2001 she held Ph.D. degree in the field of defibrillation. In 2007 she became Associate Professor. V. Krasteva has been honored with a number of awards for Outstanding Scientific Contributions for Young Scientists by the Ministry of Education and Science (2006), Bulgarian Academy of Sciences (2006), Union of Scientists in Bulgaria (2007). Her general interests are focused on development of models, methods and algorithms in the field of biomedical signal processing and electrical therapy, especially with applications in ECG instrumentation and defibrillation.

Tatyana Neycheva, Ph.D.
E-mail: tatiana@clbme.bas.bg

Tatyana Neycheva graduated Technical University - Sofia, Faculty of Communications, specialization Radio and Television Technologies in 1995. Since 1999, she is an employee in the Centre of Biomedical Engineering, Bulgarian Academy of Sciences, where in 2002 she defended her Ph.D. thesis in the field of defibrillation. Her interests are focused on ECG amplifiers and ECG signal analysis.

Assoc. Prof. Nikolay Mudrov, Ph.D.
E-mail: mudrovn@clbme.bas.bg



Nikolay Mudrov graduated Technical University - Sofia, Faculty of Electronic Engineering, specialization Electronic Engineering in 1973. In the period 1973–1998 he was working in the Medical Academy, Institute of Biomedical Engineering, where in 1983 he defended his Ph.D. thesis in the field of medical engineering. Since 1995, he is an employee in the Centre of Biomedical Engineering, Bulgarian Academy of Sciences, where he became Associate Professor. His scientific interests are in the field of biosignal amplifiers, electrical stimulators, defibrillation, physiological monitoring, biosignal analysis, physiotherapy instrumentation, ultrasonic instrumentation, bioimpedance measurements.

Prof. Zhecho Kostov, Ph.D.

Zhecho Kostov graduated Technical University – Sofia in 1958. Since 1960, he is working in the Department of Electrical Measurement Technology, where he became Associate Professor in 1975 and Professor in 1991. His Ph.D. thesis is dedicated to the transient processes in electromechanical systems. Currently he is working on measurements and odeling of electromagnetic systems.

Jean-Philippe Didon, Ph.D.
E-mail: jpdidon@schiller.fr

Jean-Philippe Didon graduated from Compiègne University of Technology (UTC), France with a PhD specialization in image and signal processing in 1996. He is currently scientific manager in SCHILLER MEDICAL SAS, France where he works since 1997. His scientific fields of interests are biomedical signal processing and defibrillation.