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A DEVICE FOR ASSISTED CARDIOPULMONARY RESUSCITATION

FIELD OF THE INVENTION

The invention relates to methods and devices for assisted cardiopulmonary resuscitation.

5 BACKGROUND OF THE INVENTION

During cardiac arrest, the heart is in a state of uncoordinated heart contractions (fibrillation) or complete standstill which prevents the flow of blood to the brain and other vital organs including the heart itself. More than 300,000 people die each year from cardiac arrest in the United States alone. It is the object of cardiopulmonary resuscitation (CPR) to maintain the
10 flow of blood and oxygen to the heart and brain so as to prevent damage until the victim's own heartbeat can be reestablished.

The simplest form of CPR, manual CPR, involves administering cycles of two ventilations followed by 15 manual chest compressions of 3.75-5 cm in depth, at a rate of about 100 compressions per minute. Manual CPR typically utilizes almost all of the rescuer's
15 musculature simultaneously so that a substantial physical effort is required on the part of the rescuer. Since CPR may be required for 20 minutes or more, the rescuer often becomes exhausted and forced to discontinue CPR and/or apply CPR incorrectly before the victim is revived or professional help arrives (Baubin *et al.*). Rescuer fatigue is therefore a significant limiting factor in the effectiveness of manual CPR.

20 While manual CPR provides active compression, it relies on passive expansion of the chest following each compression. Active compression-decompression (ACD) CPR, on the other hand, provides for both active compression and decompression by pushing the chest inward and forcibly pulling it out.

Several devices have been described for providing ACD-CPR. U.S. Patents 5,636,789,
25 5,295,481, and 5,645,522 disclose a vacuum cup which is placed directly on the victim's chest. The chest is compressed by pressing down on the vacuum cup and lifted by pulling it up so as to provide the active decompression. ACD-CPR devices, however, do not solve the problem of rescuer fatigue. In fact, 25% more work is required for performing ACD-CPR in comparison to manual CPR (Shultz *et al.*, *Resuscitation*, 29:23-31 (1995)).

30 U.S. Patent 4,928,674 discloses a pneumatic vest designed to fit around the victim's chest. The device is inflated and deflated automatically by a computer controlled compressor applying pressure to the torso from all directions. While such automatic CPR devices solve the problem of rescuer fatigue, their efficacy has not been established (Halperin *et al.*). In addition to requiring greater expertise for their operation, the fully automatic devices such as the one



disclosed in the '674 patent are extremely heavy and bulky and so are difficult to bring to the victim. Also, the set-up time of such devices may be unacceptable.

REFERENCES CITED

Baubin *et al.*, *Resuscitation*, 33:135-139 (1996).

5 Shultz *et al.*, *Resuscitation*, 29:23-31 (1995).

Halperin *et al.*, *N. Engl. J. Med.*, 329:762-768 (1993).

SUMMARY OF THE INVENTION

One object of some preferred embodiments of the invention is to reduce rescuer fatigue during application of CPR. Preferably, the applied CPR meets American Heart Association guidelines for the application of CPR. Preferably, meeting these guidelines is assisted by a device in accordance with a preferred embodiment of the invention.

An aspect of some preferred embodiments of the invention relates to using a rescuer as a "smart weight", whereby the rescuer performs a significant portion of the CPR task by shifting his/her weight to and from the victim. Preferably, a significant portion of the mechanical energy required to move a chest of the victim is provided by a mechanized device. Alternatively or additionally, such a device also assists the rescuer in shifting his weight. In a preferred embodiment of the invention, the focus of the rescuer's activity is shifted from performing mechanical work to controlling the CPR activity. Preferably, one result of the shift in focus is that the rescuer performs higher quality CPR. Alternatively or additionally, another result of the shift in focus is that the rescuer is required to perform less work, thereby he is less fatigued by the CPR and may be able to keep it up longer.

An aspect of some preferred embodiments of the invention relates to human interaction in the CPR process. In a preferred embodiment of the invention, the human functions as a "smart weight", as part of a complete CPR system which includes a mechanical device and the rescuer. In a preferred embodiment of the invention, the CPR process may be controlled by the shifting of the rescuer's weight. Thus, being an integral part of the CPR activity, the rescuer can change his activities so that the CPR being performed is what the rescuer wants to be performed. Alternatively or additionally, the rescuer can more exactly match the CPR being performed to what is required by the victim, for example based on visual and/or other feedback from the victim.

An aspect of some preferred embodiments of the invention relates to an expected setup time of a CPR device. In some embodiments of the invention, the CPR device is simply placed at a proper location on the victims chest. Thus, the set-up time is substantially the same as for purely manual CPR.

An aspect of some preferred embodiments of the invention relates to adjusting a CPR device and/or method for a particular rescuer/victim/CPR situation. In a preferred embodiment of the invention, the adjustment is effected by a rescuer using the same CPR device in a slightly different manner, for example changing his timing and/or center of gravity. Alternatively or additionally, the adjustment is effected by varying a vertical dimension of the CPR device, for example by changing a setting therein or by providing a telescopic support or a

spacer therewith. Alternatively or additionally, the adjustment is effected by changing device operating parameters, for example, waveform, frequency and/or response to sensed physiological variables.

5 An aspect of some preferred embodiments of the invention relates to assisting a rescuer in placing/removing his weight from a victim's chest. In a preferred embodiment of the invention, the assistance enables a better impulse force to be applied to the chest, resulting in more effective CPR. In a preferred embodiment of the invention, the assistance includes lifting up a rescuers weight from the victim. Alternatively or additionally, the assistance includes lowering down the rescuers weight onto the victim's chest.

10 An aspect of some preferred embodiments of the invention relates to a limited-count-use attachment element. In a preferred embodiment of the invention, the CPR device is attached to a victim's chest using an attachment element which can be used only once or a small number of times. Alternatively or additionally, the attachment element is fixed to the victim's body by itself and then the CPR device is coupled to the attachment element.
15 Preferably, one CPR is completed the CPR device is detached from the attachment element, which may remain connected to the chest. In one example, the attachment element comprises a suction cup or an adhesive pad. Alternatively or additionally, the attachment element comprises a strap which preferably encircles the victim's torso. In a preferred embodiment of the invention, the attachment element includes physiological sensors such as chest displacement
20 sensors or ECG electrodes. Alternatively or additionally, the attachment element includes active elements, such as defibrillation electrodes and/or external pacing electrodes.

There is therefore provided in accordance with a preferred embodiment of the invention, a system for assisted cardiopulmonary resuscitation to allow a rescuer to apply his/her body weight to the chest of a victim comprising:

- 25 (a) a contact surface for contacting the victim's chest;
(b) a support member for enabling the rescuer to apply his/her body weight to the contact surface;
(c) a displacer which raises or lowers the support member relative to the contact surface at a selectable frequency and speed and to a selectable height.

30 Preferably, the system include a controller which activates said displacer.

In a preferred embodiment of the invention, a system is provided for assisted cardiopulmonary resuscitation to allow a rescuer to apply his/her body weight to the chest of a victim comprising:

(a) a cylinder assembly that includes a closed cylinder having a bottom section, and a piston assembly that includes a piston, and a piston rod slidably received within said cylinder;

(b) a contact surface associated with the bottom section of said cylinder for contacting the victim's chest;

5 (c) a displacer raising the piston;

(d) a support member attached to said piston rod for enabling the rescuer to apply his/her body weight to the piston so as to rapidly depress the piston and cause the compression of the victim's chest;

(e) a controller capable of activating said means for raising the piston such that the
10 piston is raised at a selectable frequency and speed and to a selectable height.

During operation of the preferred embodiment, the rescuer kneels next to the victim's chest and places the contacting surface of the cylinder assembly on the chest of the victim, for example with the piston at the bottom of its stroke cycle. The rescuer transfers his body weight onto the support member. As the piston rises by the raising means, the rescuer's head and
15 shoulders are lifted so that the rescuer's gravitational potential energy is increased. As the rescuer's head and shoulders are lifted, his knees and hips become more bent so that his body weight is shifted from the support member to his knees. The transfer of the rescuer's body weight from the support member releases the pressure on the victim's chest, allowing the victim's chest to be decompressed. When the piston is at the top of its stroke cycle, the rescuer
20 transfers his body weight onto the support member, causing the piston to descend rapidly thereby converting the rescuer's gravitational potential energy into kinetic energy. When the rapidly descending piston hits the bottom section of the cylinder assembly, the kinetic energy of the rescuer is transferred to the victim's chest which becomes compressed, and the cycle can begin again. Those versed in the art will readily appreciate that, similar to manual CPR, some
25 preferred embodiments of the invention provide active compression but rely on passive decompression of the chest. Alternatively, in some preferred embodiments of the invention, the CPR device is coupled to the victim's chest, for example, using a suction cup, adhesive and/or a strap. When the rescuer leans further back, the chest may be pulled up, to provide active decompression. Alternatively or additionally, once the rescuer's weight is off the victim's chest,
30 active shortening of the device may cause a decompression of the chest, if the rescuer maintains his position.

The invention may optionally comprise a lowering device for lowering the piston once the rescuer has transferred his body weight to the support member. The lowering device thus

imparts kinetic energy to the piston in addition to the kinetic energy imparted to the piston through application of the rescuer's body weight to the support member.

The frequency of the cycle, the height to which the piston is raised, as well as the speed at which the piston is raised or lowered are determined by the controller and can be selected by the rescuer to match the requirements of the victim. Alternatively or additionally, the height of the device itself may be set, for example, using a telescopic support.

There is thus provided in accordance with a preferred embodiment of the invention, a system for assisted cardiopulmonary resuscitation to allow a rescuer to apply his/her body weight to the chest of a victim comprising:

- 10 a contact surface for contacting the victim's chest;
- a support member for enabling the rescuer to apply his/her body weight to the contact surface; and
- a displacer operative to move the support member relative to the contact surface.

Preferably, the system comprises a controller capable of activating the displacer to achieve a desired motion. Preferably, said desired motion comprises a desired direction. Alternatively or additionally, said desired motion comprises a desired applied force.

In a preferred embodiment of the invention, said displacer increases a displacement between said support member and said contact surface. Alternatively or additionally, said displacer decreases a displacement between said support member and said contact surface. Alternatively or additionally, said displacer comprises an electric motor. Alternatively or additionally, said controller comprises an electrical controller. Alternatively or additionally, the controller comprises a pneumatic controller.

There is also provided in accordance with a preferred embodiment of the invention, a system for assisted cardiopulmonary resuscitation to allow a rescuer to selectively apply his/her body weight to the chest of a victim comprising:

- (a) a cylinder assembly that includes a closed cylinder having a bottom section, and a piston assembly that includes a piston and a piston rod slidably received within said cylinder;
- (b) a contact surface associated with the bottom section of said cylinder for contacting the victim's chest;
- 30 (c) a displacer raising the piston; and
- (d) a support member attached to said piston rod for enabling the rescuer to apply his/her body weight to the piston so as to rapidly depress the piston and cause a compression of the victim's chest.

Preferably, the system comprises a controller capable of activating said displacer to perform a desired motion. Alternatively or additionally, said piston is moved at a selectable frequency. Alternatively or additionally, said piston is moved at a selectable speed. Alternatively or additionally, said piston is moved a selectable amount height.

5 In a preferred embodiment of the invention, the system comprises an electrocardiograph monitor and recorder coupled to the controller, wherein said controller activates and deactivating the raising means, responsive to said ECG. Alternatively, the system comprises an electrocardiograph monitor and recorder coupled to the controller and capable of producing a signal sensible by the rescuer, which signal guides cardiopulmonary resuscitation. Preferably,
10 said guidance comprises indicating to the rescuer when to stop said CPR.

In a preferred embodiment of the invention, said system includes a physiological sensor, which measures a physiological parameters of said victim. Preferably, said controller modifies said movement, responsive to values sensed by said sensor. Alternatively or additionally, said controller generates an indication to said rescuer, responsive to values sensed
15 by said sensor.

In a preferred embodiment of the invention, said displacer comprises a lowering device capable of lowering the piston so as to apply a selectable force to the victim's chest. Alternatively or additionally, the piston is raised by the introduction of a pressurized gas below the piston's surface. Preferably, the pressurized gas is air. Alternatively or additionally, the
20 pressurized gas is oxygen.

In a preferred embodiment of the invention, the piston is raised using an electric motor. Alternatively or additionally, the piston is lowered by the introduction of pressurized gas above the piston. Alternatively or additionally, the piston is lowered by an electric motor. Alternatively or additionally, the controller is operated by electricity. Alternatively or
25 additionally, the controller is pneumatic.

In a preferred embodiment of the invention, the system further comprises a ventilator coupled to the controller for the ventilation of the victim's lungs, said ventilation being coordinated with the cardiopulmonary resuscitation. Preferably, about 2 ventilations of the victim's lungs are administered following about every 15 compressions of the victim's chest.

30 In a preferred embodiment of the invention, the system comprises a defibrillator coupled to the controller for the defibrillation of the victim's heart, said defibrillation being coordinated with the cardiopulmonary resuscitation.

In a preferred embodiment of the invention, the system comprises a capnometer. Alternatively or additionally, the system comprises a blood flow meter. Alternatively or

additionally, the system comprises a strap. Preferably, the strap fixes the system onto the chest of the victim. Alternatively or additionally, the strap comprises defibrillator electrodes.

In a preferred embodiment of the invention, said contact surface comprises a suction cup. Preferably, said system is operative to be connected to said suction cup after said suction cup is attached to said victim. Alternatively or additionally, said suction cup comprises defibrillation electrodes. Alternatively or additionally, said suction cup comprises at least one physiological sensor.

In a preferred embodiment of the invention, the system further comprises a display for indicating a physiological parameter of the patient. Preferably, said display comprises an auditory display. Alternatively or additionally, said physiological parameter comprises the victim's heart rate. Alternatively or additionally, said physiological parameter comprises the victim's blood pressure. Alternatively or additionally, said physiological parameter comprises the victim's blood flow rate. Alternatively or additionally, said physiological parameter comprises the CO₂ concentration in the victim's exhaled breath. Alternatively or additionally, said physiological parameter comprises the pressure being applied to the victim's chest. Alternatively or additionally, said physiological parameter comprises the displacement of the victim's chest.

In a preferred embodiment of the invention, the system comprises a monitor capable of monitoring and storing information pertaining to the resuscitation.

Also within the scope of the present invention is the use of a system as described hereinabove for the administration of cardiopulmonary resuscitation.

BRIEF DESCRIPTION OF THE FIGURES

The invention will now be described by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 shows one embodiment of the invention;

Fig. 2 shows a cross-sectional view of the cylinder assembly, support member, and contacting surface along plane A-A in Fig. 1;

Fig. 3 shows a generalized flow chart describing the functioning of the controlling unit; and

Fig. 4 shows use of the embodiment of Fig. 1 by a rescuer for the administration of CPR to a victim, where, in (a) the piston of the embodiment is at the bottom of its stroke cycle, in (b) the piston is at the top of its stroke cycle and in (c) a superimposition of (a) and (b) is shown.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Fig. 1 shows a CPR device in accordance with a preferred embodiment of the invention, in which a closed cylinder 1 is fitted with a closely slidable piston. The piston rod 2 is attached at its upper end to a support member 3, preferably suitable for grasping by a rescuer. (Cylinder 1, the piston (not shown) and piston rod 2 constitute together said cylinder assembly.) A contact surface 4 is associated with the bottom surface of the cylinder. Preferably, contact surface 4 comprises a suction cup, an adhesive pad and/or straps, to maintain contact between the device and a victim. In a preferred embodiment of the invention, raising and/or lowering movement of piston 2 is effected by a source of compressed gas 8, for example, nitrogen, air or oxygen. In a preferred embodiment of the invention, a cylinder of gas, for example oxygen is supplied. Alternatively or additionally, a compressor, which compresses ambient air is provided. Such a compressor may, for example, utilize a rechargeable battery power supply or a combustion engine. Alternatively or additionally, other sources of external pressure may be used, for example, a wall supply of pressurized air or oxygen in a hospital. Alternatively or additionally, other methods of moving piston 2 and/or support member 3 may be used, for example hydraulic or electrical motors.

Preferably, cylinder 1 is connected via hoses 5, 6 and 7 to external pressure source 8. In a preferred embodiment of the invention, a controller 9 is interposed between the external pressure source 8 and cylinder 1, to control the movement of the piston. Preferably, the control is by regulating the flow of gas from the external pressure source 8 to the cylinder 1. Alternatively or additionally, the controller may be integrated into the cylinder assembly. In a preferred embodiment of the invention, the controller comprises a mechanical controller. Alternatively or additionally, the controller comprises an analog electrical controller (preferably with solenoid-type valves). Alternatively or additionally, the controller comprises a pneumatic or hydraulic controller. Alternatively or additionally, the controller comprises a digital controller. In a preferred embodiment of the invention, the controller is programmable.

In a preferred embodiment of the invention, contact surface 4 may be attached to the victim before the rest of the CPR device is attached to the contact surface. In one example, contact surface may comprise a suction cup. Thus, a victim's chest is exposed, the suction cup is attached at a correct location and then the rest of the CPR device is coupled to the suction cup, for example, using a ratchet connector. It is noted that the quality of the suction is not critical in some embodiments of the invention, as the suction cup is pressed anew against the victim's chest each chest compression. In a preferred embodiment of the invention, the suction

cup includes physiological sensors, such as ECG electrodes and/or active devices, such as defibrillation electrodes.

Fig. 2 shows a cross-sectional view of the cylinder assembly, support member, and contacting surface along plane A-A of Fig. 1. The cylinder may be pressurized below the piston 10 by the introduction of pressurized gas via tube 6 through valve 15 and inlet 11' located at the bottom of the cylinder wall causing the piston 10 to rise. Alternatively and optionally, the cylinder may be pressurized above the piston by introducing the pressurized gas via tube 7 through an inlet 11" and venting gas below the piston to the atmosphere through inlet 11' and valve 15, causing the piston to descend.

It will readily be seen by those versed in the art that the invention may be varied without departing from the scope or spirit of the invention. For example, other devices for raising or lowering the piston such as utilizing an electric motor instead of a pressurized gas as shown in Fig. 1, are also applicable. The raising and lowering devices may share one or more components, such as the source of pressurized gas in Fig. 1, or may be completely separate and independent. The controller and the cylinder assembly may be separate facilities as shown in Fig. 1 or may be integrated into a single unit. Alternatively or additionally, the raising action and the lowering action may be provided by separate means, for example a hydraulic one for raising and a pneumatic one for lowering. In a particular preferred embodiment of the invention, raising and/or lowering of piston 2 is achieved using an electric motor, which is powered by an integral battery, yielding a compact CPR device, possibly with no trailing cords or tubes.

Fig. 3 shows a generalized flow chart describing the functioning of the controller 6. An oscillator which may for example be electric or pneumatic and whose frequency may be selected regulates the intermittent opening of valves a and b. When the signal produced by the function generator is greater than 0, valve a is open, valve b closed, and valve 15 is closed to the atmosphere, so that pressurized gas flows from the external source 8 shown in Fig. 1 via tube 5 to tube 6 and then into the cylinder 1 through inlet 11' causing the piston to rise. Simultaneously, gas leaves the cylinder through inlet 11' and tube 7 and is released to the atmosphere. Otherwise valve b is open, valve a closed and valve 15 is open to the atmosphere so that gas flows from the external source 8 via tube 5 to tube 7 and then into the cylinder 1 through valve 15 and inlet 11" causing the piston to descend. Simultaneously, gas leaves the cylinder through inlet 11' and valve 15 and is vented to the atmosphere. Whilst Fig. 3 described an electrically based controller, those versed in the art will readily appreciate that the specific

structure of Fig. 3, is only one out of many possible variants. Thus, by way of a non-limiting example the controller 3, may be partially or fully pneumatically operated.

Fig. 4 shows the administration of CPR, in accordance with a preferred embodiment of the invention. In Fig. 4a, the contact surface 4 of the cylinder 1, has been placed on the chest of the victim 12 with the piston 10 at the bottom of its stroke cycle. An optional strap 13 around the victim's chest and/or shoulders preferably aids in fixing the device in place during operation. The rescuer 14 has transferred most of his weight to the support member 3. As the piston rises due to the introduction of pressurized gas into cylinder 1 below piston 10 via valve 15 and inlet 11', the rescuer's head and shoulders are lifted so that the rescuer's gravitational potential energy is increased. As the rescuer's head and shoulders are lifted, his knees and hips become more bent so that his body weight is shifted from the support member 3, primarily to his knees. The transfer of the rescuer's body weight from the support member 3 releases the pressure on the victim's chest, allowing the victim's chest to be decompressed. Also, additional vertical motion of the rescuer may easier and/or not apply pressure to the victim's chest.

In Fig. 4b, the piston 10 is at the top of its stroke cycle, and the rescuer has transferred his body weight onto the support member 3. Valve 15 is now opened to the atmosphere and pressurized gas is (optionally) introduced into cylinder 1 above the piston 10 via inlet 11". Simultaneously, pressurized gas below the piston 10 is allowed to rapidly escape via inlet 11', through valve 15. The combination of the body weight of the rescuer being applied to the support member 3 and the pressurized gas above the piston cause the piston to descend rapidly thereby converting the rescuer's gravitational potential energy into kinetic energy. When the rapidly descending piston hits the bottom section of the cylinder assembly, the kinetic energy of the rescuer is transferred to the victim's chest which becomes compressed, and the CPR cycle can begin again.

The frequency of the cycle, the height to which the piston is raised, the range of motion of the piston and/or the speed at which the piston is raised or lowered are determined by the controller 9 and can be (if desired) selected by the rescuer to match the requirements of the victim, be modified during the rescue and/or be pre-configured. Selection of the frequency of the cycle, the height to which the piston is raised or the speed at which the piston is raised or lowered by the rescuer, allows the rescuer to control, for example, the displacement of the victim's chest and/or the pressure applied thereto. Alternatively or additionally, other parameters of the piston motion may be controlled, for example a relationship between displacement and velocity or acceleration (of the piston), applied force and/or delay between compressions.

Fig. 4c is a superimposition of Figs. 4a and b showing that only small vertical and rotational displacements of the rescuer's body are involved in the passage from the posture of Fig. 4a (shown in dotted line in Fig. 4c) to the posture of Fig. 4B (shown in solid line in Fig. 4c). Only small movements of the musculature are therefore required so that the physical exertion demanded of the rescuer, in some embodiments of the invention, is substantially less than for manual CPR.

The embodiment of Fig. 1 was tested on a state of the art CPR mannequin equipped with a computer and appropriate mechanical sensors by professional and non-professional rescuers. The results showed that the rescuer's oxygen consumption and elevation of heart rate are significantly less while using the CPR device and his/her endurance is significantly enhanced in comparison to manual CPR. Moreover, it is believed that the effectiveness of the CPR provided by the invention is at least equal to that of manual CPR.

Several variations are contemplated within the scope and spirit of the invention. The invention may optionally contain a defibrillator, which is coupled to the controller and capable of applying electrical shocks to the victim simultaneously with the administration of CPR as disclosed for example in U.S. Patent 4,928,674.

The invention may further optionally contain an electrocardiograph (ECG) monitor and recorder for monitoring the victim's heart which is coupled to the controller as described for example in U.S. Patent 4,927,674. The controller may utilize suitable means for analyzing the ECG signal so as to activate or deactivate the raising means, or produce a signal sensible by the rescuer informing him when (and/or if) to start and/or stop CPR. The controller could, if desired, also regulate the timing, duration, waveform and/or intensity of the electric shock provided by the defibrillator, responsive to the ECG signals, the motion of the piston, the history of CPR application, ECG traces and/or defibrillation shocks applied and/or sensed physiological variables, current and/or historical values. Such an analysis of present and/or past situations may also be used to guide a rescuer in applying CPR and/or to determine settings or device parameters, possibly with the device automatically changing the settings. Alternatively or additionally, the controller could indicate that defibrillation is about to be performed, so a rescuer will let go of the patient and possibly remove the CPR device, to avoid electrocution and/or damage to the device. Alternatively or additionally, the CPR device is double insulated. Alternatively or additionally, tubes to an external pressure source are insulating.

The invention could be provided with an optional strap to be placed around the victim's chest so as to hold the device in place, or to apply the electrodes of a defibrillator to the victim's chest. Alternatively or additionally, such a strap may include a strain gauge, to

estimate displacement of the victim's chest. Alternatively or additionally, the displacement is estimated using an accelerator incorporated in the CPR device and/or in the strap. Preferably, the measured acceleration is can be used to determine impulse force. Alternatively or additionally, a twice-integrated acceleration may be used to determine chest displacement.

5 The invention may optionally contain a ventilator for ventilating the victim's lungs simultaneously with the administration of CPR. The ventilator could be regulated by the controller to coordinate the ventilation cycles with the CPR cycles as disclosed in U.S. Patent 4,928,674. By way of example, the ventilator could be coordinated with the raising means in such a fashion that two ventilations of the victim's lungs are administered following every 15
10 compressions of the victim's chest. Such ventilation may be automatically stopped once breathing of the victim is detected.

 The invention may further be provided with an optional capnometer, to inform the rescuer and/or the controller of the concentration of CO₂ in the victim's exhaled breath, so as to provide an indication as to the quality of the CPR.

15 The invention may further be provided with a blood flow meter to inform the rescuer and/or the controller of the victim's blood flow rate so as to provide an indication as to the quality of the CPR.

 The invention may further be provided with an optional pressure indicator, to inform the rescuer and/or the controller of the pressure being applied to the victim's chest during CPR,
20 so as to allow the rescuer and/or the controller to modify the pressure being applied.

 The invention may further be provided with an optional device capable of informing the rescuer by means of a sensible signal of sensed physiological parameters, such as one or more of the following parameters: the victim's heart rate and/or other ECG characteristics, blood pressure or blood flow rate, the CO₂ concentration in the victim's exhaled breath, the pressure
25 being applied to the victim's chest, and the displacement of the victim's chest. In a preferred embodiment of the invention, the sensible signal comprises an audio signal, for example a beep or synthetic speech. Alternatively or additionally, the signal comprises a display. Alternatively or additionally, the sensed parameters are analyzed and a composite signal is supplied, for example a green light if the CPR is progressing as it should and a red light if not.

30 In a preferred embodiment of the invention, the controller is capable of closed loop behavior, for example, if an applied impulse pressure to the chest is above a threshold, the controller stops and/or reduces its lowering action, to reduce the impulse pressure. Alternatively or additionally, other parameters of the device may be automatically controlled, responsive to the above measured physiological variables, for example, range of motion,

velocity profile of the piston, delay between compressions and/or application of external electrical stimulation.

Alternatively or additionally, the controller can determine if the CPR activity is meets certain criteria (such as the AHA guidelines) and provide a warning to a rescuer if not. For example, a warning may be displayed if the applied pressure is too high and/or if the compression rate is too low. Alternatively or additionally, the CPR device may stop operation is incorrectly used. Alternatively or additionally, the CPR device may suggest an action to the user, for example to increased the applied pressure. Alternatively or additionally, the controller reports if the rhythm of the CPR is adequate. Alternatively or additionally, the controller senses that a rescuer is not properly utilizing the device, for example, not shifting his weight properly, so the controller is required to assist the downward motion to a greater extent or if the rescuer's weight is never removed from the victim's chest.

In a preferred embodiment of the invention, the CPR device provides the rhythm for CPR (and/or ventilation) and the rescuer follows it (possibly being synchronized using an audio signal). Preferably, the motion of the piston is completely controlled by the controller. Alternatively, the movement of the piston may follow the rescuer's lead. In one example, a new raising/lowering cycle starts when a user shifts his weight onto the support member and/or compresses the piston by a predetermined amount. In one example, such control may not require a controller, for example, by inlet and/or valves in the CPR device being directly opened and closed by the pressure on the support member. Alternatively, the support member may include controls, such as buttons, for effecting the raising and/or lowering of the piston. Alternatively or additionally, the control may be by voice control.

The invention may further be provided with a monitor capable of monitoring and storing information pertaining to the resuscitation, such as the time the resuscitation commenced, the time when the resuscitation was terminated, the number of cycles performed, the frequency of the cycles, the percentage of defective cycles, the frequency and type of errors, the force applied during each cycle, events where the guidelines were not met and/or the displacement of the chest during each cycle. The monitor may be on line or off line with an external computer.

The present invention has been described with a certain degree of particularity, but it should be understood that various modifications and alterations may be made without departing from the scope or spirit of the invention. For example, it will be evident to a person versed in the art that the invention can be constructed having a raising or a lowering device not comprising a piston. As an example, a raising or lowering device comprising an electrical

motor instead of a piston may be used (not shown). In addition, a multiplicity of various features, both of methods and of devices have been described. It should be appreciated that different features may be combined in different ways. In particular, not all the features shown above in a particular embodiment are necessary in every similar preferred embodiment of the invention. Further, combinations of the above features are also considered to be within the scope of some preferred embodiments of the invention. It should also be appreciated that many of the embodiments are described only as methods or only as apparatus. The scope of the invention includes devices for performing the methods and methods of using the devices. In addition, the scope of the invention includes methods of using, constructing, calibrating and/or maintaining the apparatus described herein. When used in the following claims, the terms "comprises", "comprising", "includes", "including" or the like means "including but not limited to".

CLAIMS

1. A system for assisted cardiopulmonary resuscitation to allow a rescuer to apply his/her body weight to the chest of a victim comprising:

5 a contact surface adapted for contacting the victim's chest and for maintaining a fixed location relative to said chest;

a support member adapted for having a rescuer's body weight applied thereto, said support member adapted to couple said weight to said contact surface; and

10 a displacer adapted for moving the support member up and/or down relative to the contact surface, while said rescuer's weight is applied thereto and while said contact surface is in contact with said victim's chest.

2. A system according to claim 1, comprising

a controller capable of activating the displacer to achieve a desired motion.

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3. A system according to claim 2, wherein said desired motion comprises a desired direction.

4. A system according to claim 2 or claim 3, wherein said desired motion comprises a
20 desired applied force.

5. A system according to any of claims 1-4, wherein said displacer increases a
→ displacement between said support member and said contact surface.

25 6. A system according to any of claims 1-5, wherein said displacer decreases a displacement between said support member and said contact surface.

7. A system according to any of claims 1-6, wherein said displacer comprises an electric motor.

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8. A system for assisted cardiopulmonary resuscitation to allow a rescuer to selectively apply his/her body weight to the chest of a victim comprising:

(a) a cylinder assembly that includes a closed cylinder having a bottom section, and a piston assembly that includes a piston and a piston rod slidably received within said cylinder;

(b) a contact surface associated with the bottom section of said cylinder for contacting the victim's chest and adapted for maintaining a fixed location relative to said chest;

(c) a displacer which moves the piston up and/or down; and

(d) a support member attached to said piston rod said support member and said
5 piston rod adapted to couple said weight to said contact surface and enabling the rescuer to apply his/her body weight to the piston so as to rapidly depress the piston and cause a compression of the victim's chest.

9. A system according to claim 8, comprising:

10 a controller capable of activating said displacer to perform a desired motion.

10. A system according to claim 8 or claim 9, wherein said piston is moved at a selectable frequency.

15 11. A system according to any of claims 8-10, wherein said piston is moved at a selectable speed.

12. A system according to any of claims 8-11, wherein said piston is moved a selectable amount.

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13. A system according to claim 2 or claim 9, further comprising an electrocardiograph monitor and recorder coupled to the controller, wherein said controller activates and deactivates the displacer, responsive to said ECG.

25 14. A system according to claim 2 or claim 9, further comprising an electrocardiograph monitor and recorder coupled to the controller and capable of producing a signal sensible by the rescuer, which signal guides cardiopulmonary resuscitation.

15. A system according to claim 14, wherein said guidance comprises indicating to the
30 rescuer when to stop said CPR.

16. A system according to claim 2 or claim 9, wherein said system includes a physiological sensor, which measures a physiological parameter of said victim.

17. A system according to claim 16 said sensor comprises a capnometer.
18. A system according to claim 16 said sensor comprises a blood flow meter.
- 5 19. A system according to any of claims 16-18, wherein said controller modifies said movement, responsive to values sensed by said sensor.
20. A system according to any of claims 16-19, wherein said controller generates an indication to said rescuer, responsive to values sensed by said sensor.
- 10 21. A system according to any of claims 8-20, wherein said displacer comprises a lowering device capable of lowering the piston so as to apply a selectable force to the victim's chest.
22. A system according to any of claims 8-21, wherein the piston is raised by the
15 introduction of a pressurized gas below the piston's surface.
23. A system according to claim 22, wherein the pressurized gas is air.
24. A system according to claim 22, wherein the pressurized gas is oxygen.
- 20 25. A system according to any of claims 8-21, wherein the piston is raised using an electric motor.
26. A system according to any of claims 8-21, wherein the piston is lowered by the
25 introduction of pressurized gas above the piston.
27. A system according to any of claims 8-21, wherein the piston is lowered by an electric motor.
- 30 28. A system according to claim 2 or claim 9, wherein the controller is operated by electricity.
29. A system according to claim 2 or claim 9, wherein the controller is pneumatic.

30. A system according to any of the preceding claims, further comprising a ventilator coupled to the controller for the ventilation of the victim's lungs, said ventilation being coordinated with the cardiopulmonary resuscitation.
- 5 31. A system according to claim 15, in which about 2 ventilations of the victim's lungs are administered following about every 15 compressions of the victim's chest.
32. A system according to any of the preceding claims further comprising a defibrillator coupled to the controller for the defibrillation of the victim's heart, said defibrillation being
10 coordinated with the cardiopulmonary resuscitation.
33. A system according to any of the preceding claims, further comprising a strap.
34. A system according to claim 33, wherein the strap fixes the system onto the chest of the
15 victim.
35. A system according to claim 33 or claim 34, wherein the strap comprises defibrillator electrodes.
- 20 36. A system according to any of the preceding claims, wherein said contact surface comprises a suction cup.
37. A system according to claim 36, wherein said system is operative to be connected to said suction cup after said suction cup is attached to said victim.
25
38. A system according to claims 36 or claim 37, wherein said suction cup comprises defibrillation electrodes.
39. A system according to any of claims 36-38, wherein said suction cup comprises at least
30 one physiological sensor.
40. A system according to any one of the preceding claims, further comprising a display for indicating a physiological parameter of the patient.

41. A system according to claim 40, wherein said display comprises an auditory display.

42. A system according to claim 40 or claim 41, wherein said physiological parameter comprises the victim's heart rate.

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43. A system according to any of claims 40-42, wherein said physiological parameter comprises the victim's blood pressure.

44. A system according to any of claims 40-43, wherein said physiological parameter
10 comprises the victim's blood flow rate.

45. A system according to any of claims 40-44, wherein said physiological parameter
) comprises the CO₂ concentration in the victim's exhaled breath.

15 46. A system according to any of claims 40-45, wherein said physiological parameter comprises the pressure being applied to the victim's chest.

47. A system according to any of claims 40-46, wherein said physiological parameter
comprises the displacement of the victim's chest.

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48. The system according to any one of the preceding claims, further comprising a monitor capable of monitoring and storing information pertaining to the resuscitation.

49. Use of the system of any of the preceding claims, for the administration of
)
25 cardiopulmonary resuscitation.

50. A system according to claim 1 or claim 8, wherein said rescuer's weight is transferred to said patient's chest substantially only via said contact surface.

30 51. A system according to any of claims 1-8, wherein said displacer is operative to apply said rescuer's weight as an impulse to said chest.

52. A system according to any of claims 1-8, wherein said displacer is operative to lift said rescuer's weight away from said chest.

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