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(54) **Apparatus for enhancement of chest compressions during CPR**

Apparat zur Verbesserung des Pressens des Brustkorbs während einer kardiopulmonaren Wiederbelebung

Appareil pour le perfectionement de compression thoracique pendant une réanimation respiratoire

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EP 1 491 176 B1

Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part application of and claims priority U.S. Application Serial No. 10/609,001, filed on June 27, 2003.

TECHNICAL FIELD

[0002] This invention relates to the devices for assisting cardiac resuscitation.

BACKGROUND

[0003] This invention relates to the field of cardiac resuscitation, and in particular to devices for assisting rescuers in performing chest compression during cardio-pulmonary resuscitation (CPR). Chest compression during CPR is used to mechanically support circulation in subjects with cardiac arrest, by maintaining blood circulation and oxygen delivery until the heart is restarted. The victim's chest is compressed by the rescuer, ideally at a rate and depth of compression in accordance with medical guidelines, e.g., the American Heart Association (AHA) guidelines. One key step for creating blood flow through the heart is to release the chest adequately after each chest compression. The chest should be released sufficiently to create a negative pressure in the chest, to facilitate venous filling of the heart and increased blood flow upon the next chest compression. If the chest is not released adequately, a positive thoracic pressure will remain which will hinder venous return and right atrial filling. Other key CPR parameters are maximal velocity of compression, compression depth, and average velocity. Compression depth and average velocity, together, provide good indication of potential blood flow volume. Maximal velocity of compression is an important factor in proper mitral valve closure and higher blood flow volume.

[0004] Sensors have been suggested for detecting the depth of chest compression. An accelerometer (with its output integrated to estimate depth) was disclosed, for example, in Freeman U.S. Application No. 09/794,320, U.S. Patent No. 6,306,107 and U.S. Patent No. 6,390,996. Force (pressure) sensors were disclosed, for example, in Groenke U.S. Patent No. 6,125,299. Force sensors provided no way of determining absolute displacement, as the compliance of the thoracic cage varies considerably from person to person. Accelerometers do not provide an indication of whether or not the chest is being released. They calculate displacement by double integration, which can result in a significant DC offset. U.S. Patent No. 6,306,107 attempted to address the DC offset problem by incorporating a force sensor as a switch to indicate onset and conclusion of compression. The prior art has also employed mechanical pressure gauges to indicate to the rescuer the amount of force or pressure being applied to the chest. But these prior art uses of an accelerometer and/or force sensor have not provided a good solution to providing the rescuer with useful feedback as to whether the chest has been sufficiently released. Differences in compliance of the thoracic cage from one individual to another means that each individual will generally be able to support different amounts of force on the sternum without significant displacement occurring.

[0005] Increasingly, automated external defibrillators (AEDs) are used by rescuers treating victims of cardiac arrest for the delivery of defibrillatory shocks with the minimum of delay. The algorithms contained in the currently-available AEDs call for 'hands off periods during which electrocardiographic (ECG) analysis is performed by the device and the rescuer withholds compressions. Compressions must be withheld because the accuracy of current rhythm analysis algorithms in AEDs is severely degraded by the artifact induced by the chest compressions. These AEDs also call for the rescuer to check for pulse or for signs of circulation during which time no compressions are performed. It has been shown in several studies that interruptions in the performance of chest compressions off short a time as 20 seconds can dramatically reduce the probability of the return of spontaneous circulation (ROSC), a key survival measure. Other studies have also shown that the minimum amount of time required for the 'hands off period is 20 seconds. There is therefore a need for the ability of AEDs to perform rhythm analysis while the rescuer continues with the chest compressions uninterrupted.

[0006] EP 1057451 discloses a system for measuring parameters during chest compression including a pressure pad containing an accelerometer, a force activated switch and a calculation unit. Parameters such as depression distance, duration or rate of depressions during chest compression are registered. Feedback to the user may be provided in the form of a visual representation or in the form of corrective and instructive messages.

[0007] US 2001/0047140 discloses a combined defibrillation and CPR pad including a compression-sensing element or a force-sensing element, with a resuscitation control system configured to receive compression or force information from the compression or force-sensing element. The resuscitation control system is able to provide a rescuer with compression or force feedback during CPR, including the rate at which the rescuer performs CPR.

[0008] WO 02/15836 discloses a cardiopulmonary resuscitation device capable of determining displacement of a

region of a patient's chest to which force is applied so as to cyclically compress and decompress the chest and administer thereby CPR to the patient. Displacement of the chest region is determined by double integration over time of acceleration of the chest region. A visual display screen may be provided to display the CPR force and compression displacement generated by a processor to cue the rescuer to his or her performance of the CPR

[0009] Gruben et al, in system for Mechanical Measurements During Cardiopulmonary Resuscitation in Humans", IEEE Transactions on Biomedical Engineering Vol 37, No. 2, February 1990, disclose a system for measurement of the mechanical properties of the human chest and the resultant vascular pressures. The system enables real-time feedback of sternal force and displacement, with vascular pressure provided via chart recordings. Audible signals are provided as an aid in maintaining desired compression rate and duration.

[0010] US 5,496,257 discloses a portable apparatus for assisting a rescuer to administer CPR on a patient. Chest compressions are applied through the apparatus. The apparatus monitors compression force, rate of compressions and blood flow. Information is provided to the rescuer so that CPR is properly administered.

[0011] US 5,589,639 discloses a force sensing system for a CPR device, including a processor for processing an electric reactance signal from a force sensing device into an intelligible output signal which is shown on a display device.

SUMMARY

[0012] In a first aspect, the invention features an apparatus for assisting a rescuer in performing chest compressions during CPR on a victim, the apparatus comprising a pad or other structure configured to be applied to the chest near or at the location at which the rescuer applies force to produce the chest compressions, at least one sensor connected to the pad, the sensor being configured to sense movement of the chest, processing circuitry for processing the output of the sensor to determine whether the rescuer is substantially releasing the chest following chest compressions, and at least one prompting element connected to the processing circuitry for providing the rescuer with a visual or auditory prompt indicating as to whether the chest is not being sufficiently released following chest compressions.

[0013] Preferred implementations of this aspect of the invention may incorporate one or more of the following. The pad or other structure may be a pad to which force is applied by rescuer. The sensor may include an accelerometer. The sensor may include a force (or pressure) sensor. The sensor may include a velocity sensor. The sensor may include both a force (or pressure) sensor and an accelerometer or velocity sensor. The prompting device may include a speaker for delivering an audible message to the rescuer. The prompting device may include a display for delivering a visual message to the rescuer. The apparatus may be part of an external defibrillator. The external defibrillator may be an AED. The processing circuitry may include a digital processor executing software. Determining whether the rescuer is substantially releasing the chest may comprise analyzing motion of the chest. Analyzing motion of the chest may comprise analyzing features or the shape of a waveform representing chest motion. The apparatus may comprise both a sensor to sense movement of the chest and a sensor to sense force applied to the chest, and the processing circuitry may use outputs of both sensors to provide information representative of chest compliance. The information representative of chest compliance may be used to determine a level of applied pressure/force that corresponds to a substantial release of the chest.

[0014] In a second aspect, described herein is an apparatus for assisting a rescuer in performing chest compressions during CPR on a victim, the apparatus comprising a pad or other structure configured to be applied to the chest near or at the location at which the rescuer applies force to produce the chest compressions, and at least one velocity sensor connected to the pad, the velocity sensor being configured to sense the velocity of movement of the chest.

[0015] Preferred implementations of this second aspect may incorporate one or more of the following. The apparatus may further comprise processing circuitry for processing the output of the velocity sensor to estimate the displacement of the chest. The processing circuitry may have the capability to integrate an output of the velocity sensor. The velocity sensor may be configured to be located approximately adjacent to the location at which the body is compressed. The velocity sensor may be configured to be positioned to sense the relative velocity between opposite surfaces of the chest. The velocity sensor may comprise a conductor and a magnet, and velocity may be sensed by sensing the current induced in the conductor by relative motion between the conductor and the magnet. The magnet may comprise one of a permanent magnet and an electromagnet. The conductor and magnet may be positioned on opposite surfaces of the chest. The conductor may comprise a coil that is unitary with a defibrillation electrode pad. The conductor and magnet each may comprise a coil that is unitary with a defibrillation electrode pad. The magnet may comprise an electromagnet and the electromagnet may produce a magnetic field that oscillates at a frequency greater than 1 KHz, and may further comprise coil detection circuitry to which the coil is connected, wherein the coil detection circuitry may be capable of synchronously demodulating the detected signal to reduce susceptibility to drift and noise. The apparatus may further comprise circuitry for acquiring ECG signals from the victim, and the processing circuitry may have the capability to process the output of the velocity sensor and the ECG signals to reduce ECG artifacts from chest compressions by use of velocity sensor output.

[0016] In a third aspect, described herein is an apparatus for assisting a rescuer in performing chest compressions during CPR on a victim, the apparatus comprising a pad or other structure configured to be applied to the chest near or

at the location at which the rescuer applies force to produce the chest compressions, at least one motion sensor connected to the pad, the motion sensor being configured to sense movement of the chest, processing circuitry for processing the output of the motion sensor to estimate the maximum velocity of compression of the chest, and at least one prompting device connected to the processing circuitry for providing the rescuer with information representative of the maximum velocity of compression. In preferred implementations of this aspect of the invention, the motion sensor may comprise a velocity sensor.

[0017] In a fourth aspect, described herein is a method of determining chest compression during CPR, the method comprising applying a motion sensor to the chest of a patient at a location near or at the location at which a rescuer applies force to produce chest compressions, determining chest displacement from analysis of features of the motion waveform produced by the motion sensor.

[0018] Preferred implementations of this fourth aspect may incorporate one or more of the following. The motion sensor may be a velocity sensor. The motion sensor may be an accelerometer. The method may further comprise deciding from the analysis of features of the acceleration waveform whether or not a rescuer has sufficiently released the patient's chest. The method may further comprise processing the output of the accelerometer to provide velocity and acceleration waveforms. The method may further comprise processing the output of the accelerometer to provide velocity and acceleration waveforms, and analyzing the velocity and acceleration waveforms to determine whether or not a rescuer has sufficiently released the patient's chest. The analysis of velocity waveforms may include determining the maximal velocity of compression. Determining chest displacement from analysis of features may comprise determining onset and completion times for a compression cycle from the features of the waveforms. Determining chest displacement may further comprise integrating the acceleration waveform over a time segment defined by the onset and completion times. The method may further comprise analyzing the features of the upstroke portion of the waveforms to determine whether there has been sufficient release of the chest. The method may further comprise prompting a rescuer based as to whether compressions are within desired limits on compression depth and compression release. The prompts to the rescuer may be based on multi-cycle trends, so that they are not immediately influenced by the rescuer taking a brief break in the application of CPR. The method may further comprise determining chest compliance, and using the determined chest compliance to adjust the level of pressure/force that the rescuer is permitted to apply at the end of a compression stroke without being prompted as to insufficiently releasing the chest. The features determined from the waveforms may include one or more of the following: width, amplitude, area, center of mass, skewness, height/width ratio, TAR, TAMPR and TWR. The features may be used to make a decision as to whether the chest of the victim has been sufficiently released. Decisions may be made using either standard decision logic, fuzzy-logic decision methodology, or statistical estimation.

[0019] In a fifth aspect, described herein is a method of analyzing ECG signals during application of CPR, the method comprising detecting ECG signals during application of chest compressions, detecting the output of a sensor from which information on the velocity of chest compressions can be determined, and using the information on the velocity to reduce at least one signal artifact in the ECG signal resulting from the chest compressions.

[0020] Preferred implementations of this fifth aspect may incorporate one or more of the following. The sensor may be a velocity sensor, and the information on the velocity may be determined from the velocity sensor. The sensor may be an accelerometer, and the information on the velocity may be determined from integration of the output of the accelerometer. Using the information on the velocity to reduce at least one signal artifact in the ECG signal may comprise time aligning the ECG signals with the velocity. Using the information on the velocity to reduce at least one signal artifact in the ECG signal may comprise an adaptive filter that is adjusted to remove chest compression artifacts. Using the information on the velocity to reduce at least one signal artifact in the ECG signal may comprise feed forward active noise cancellation. Using the information on the velocity to reduce at least one signal artifact in the ECG signal may comprise determining a cutoff frequency for a filter that separates the ECG signal from chest compression artifacts.

[0021] In a sixth aspect, described herein is an apparatus for assisting a rescuer in performing chest compressions during CPR on a victim, the apparatus comprising a pad or other structure configured to be applied to the chest near or at the location at which the rescuer applies force to produce the chest compressions, at least one motion sensor connected to the pad, the motion sensor being configured to sense movement of the chest, at least one force (or pressure) sensor connected to the pad, the force sensor being configured to sense force applied to the chest, and processing circuitry for processing the output of the motion sensor and force sensor to estimate the compliance of the chest.

[0022] Preferred implementations of this sixth aspect may incorporate one or more of the following. The estimated compliance and the output of the force sensor may be used to determine the depth of compression of the chest. The motion sensor may be an accelerometer, and the output of the accelerometer may be used primarily for estimating chest compliance, and compression depth during CPR may be estimated by using the estimated compliance to convert the output of the force sensor into estimated compression depth. The output of the accelerometer may be used during limited time intervals for estimating chest compliance, and outside of those limited time intervals chest compression maybe determined from the estimated compliance and the output of the force sensor without substantial use of the output of the accelerometer. The estimated compliance and the output of the force sensor may be used to determine whether the

chest has been substantially released.

[0023] In a seventh aspect, described herein is an apparatus for assisting a rescuer in performing chest compressions during CPR on a victim, the apparatus comprising a pad or other structure configured to be applied to the chest near or at the location at which the rescuer applies force to produce the chest compressions, at least one bistable mechanical element that when depressed provides tactile feedback to the hand of the rescuer upon the start of a compression and at the end of a compression.

[0024] Preferred implementations of this seventh aspect may incorporate one or more of the following. The mechanical element may comprise a dome that collapses under pressure and returns to a dome shape on release of pressure. The bistable mechanical element may further provide audible feedback at least at the end of a compression. The tactile feedback at the end of a compression may occur at approximately an applied force corresponding to substantial release of the chest, so that the tactile feedback serves as feedback to the rescuer that the chest has been substantially released.

[0025] The invention provides numerous advantages. It provides a more accurate and detailed measure of compressions during CPR, e.g., by analyzing such compression/decompression cycle parameters as compression velocity and completeness of decompression release. And features of the velocity and acceleration waveforms may be analyzed to maximize CPR performance. E.g., the invention permits analysis of maximal velocity of compression, which is an important factor in proper mitral valve closure and higher blood flow volume.

[0026] The invention may obviate the need for a secondary information channel, e.g., a force sensor, to provide the accuracy necessary for the use of acceleration to accurately measure displacement. The invention includes new methods for the analysis of the acceleration waveform that allow for decreased offset drift and improved displacement accuracy. The methods also provide for the ability to determine parameters relating to the quality of the compression/decompression cycle by morphological analysis of the acceleration and velocity waveform. Multiple parameters may be determined via the analysis and then combined in making a decision regarding chest release or other generalized descriptor of compression/decompression quality. The methods used may include standard decision logic (e.g., IF-THEN-ELSE) or may involve methods such as fuzzy-logic decision methodology or statistical estimation such as Bayesian methods.

[0027] Direct physiological measurements of perfusion and oxygenation, such as end-tidal carbon dioxide ($EtCO_2$) and pulse oximetry, can provide additional feedback to the CPR control algorithm.

[0028] By determining chest compliance, some implementations of the invention overcome the difficulty of using a pressure/force sensor for determining the onset and release of compression. The compliance of the thoracic cage varies from person to person, and therefore each individual will generally be able to support different amounts of force on the sternum without any displacement occurring. In some implementations of the invention, compliance is estimated from measurements of force (or pressure) and chest motion during compressions. The estimated compliance can be used to adapt the chest-released force threshold to patients with differing chest compliance. Without adapting the threshold to the victim's chest compliance, the chest-released force threshold tends to have to be set quite low, to assure substantial release even on patients with large compliance. This can result in requiring the rescuer to release nearly all force from the chest, interfering with the process of CPR itself and confusing the rescuer with what appears to be irrelevant and interfering commands.

[0029] Using a velocity sensor (as proposed with some aspects of the invention), can provide a more accurate and less noise sensitive measure for determining displacement. It requires only one integration to calculate displacement from velocity, thus reducing offset error, and it requires only one differentiation to calculate acceleration thus reducing high frequency noise susceptibility. Additionally, velocity in this implementation is a differential configuration that measures relative velocity between the front and back of the thorax, unlike acceleration which is inertial and whose motion is relative to the Earth. Differential velocity measurement provides a significantly improved performance during patient transport such as in an ambulance or on an airplane. In fact, the vibration and motion may make the acceleration for the most part unusable in these situations.

[0030] Magnetic induction may be used to generate a voltage proportional to the relative velocity between a magnet and coil. The magnet may take the form of a permanent magnet, but preferably it is an electromagnet. The use of an electromagnet serves two main purposes: it can be used to calibrate the setup after the electrodes have been applied to the patient, and it can be used to provide a synchronous modulation/demodulation of the signal to improve accuracy and minimize susceptibility to noise and artifact.

[0031] The magnetic pickup and induction coils may be incorporated into defibrillation pads. One defibrillation pad can be placed on the left thorax and another defibrillation pad can be placed on the victim's back in the left scapular area. These are excellent locations for defibrillation and provide a good placement to generate magnetic flux changes proportional to sternal displacement. The coils can incorporated directly into the outer edge of each of the defibrillation electrodes. Alternatively, if the desired electrode position is anterior/anterior with both electrodes on the front of the chest, a separate backboard panel may be supplied which is placed under the patient and contains the receiving coil.

[0032] The invention's use of velocity sensor, which may make it possible to perform ECG analysis without a "hands off" period provides improved filtering and rhythm analysis.

[0033] Other features and advantages of the invention will be apparent from the following detailed description and

drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0034]

FIG 1 is a diagram of one implementation including an AED and an accelerometer and pressure/force sensor built into a chest-mounted pad.
FIG 2 shows sample signals recorded during CPR with the implementation of FIG 1.
FIG 3 is a diagram of another implementation including an AED with a membrane switch and an accelerometer.
FIG 4 shows sample signals recorded during CPR with the implementation of FIG 3.
FIG 5 depicts acceleration, velocity, and displacement for a single compression cycle.
FIG 6 is a block diagram of another implementation.
FIG 7 depicts acceleration, velocity, and displacement for two compression cycles.
FIGS. 8, 9A, and 9B show an implementation in which magnetic induction elements are built into electrodes placed in anterior and posterior locations on the thorax.
FIG 10 is an enlarged view of the composition of the electrode pad of FIGS. 9A.
FIG 11 is a block diagram of a synchronous detector implementation.
FIG 12 is a block diagram of a filtered-X least mean squares (FXLMS ANC) algorithm.
FIG 13 is an implementation using the algorithm of FIG 12.
FIG 14 shows two spectral power distributions related to the implementation of FIG 13.
FIG 15 is a block diagram of another implementation.

DETAILED DESCRIPTION

[0035] There are a great many possible implementations of the invention, too many to describe herein. Some possible implementations that are presently preferred are described below. It cannot be emphasized too strongly, however, that these are descriptions of implementations of the invention, and not descriptions of the invention, which is not limited to the detailed implementations described in this section but is described in broader terms in the claims.

[0036] FIG. 1 shows a schematic of a preferred implementation. This implementation includes an accelerometer (and accelerometer housing), force sensor built into a pressure pad, and an AED which is electrically connected to the accelerometer and force sensor and contains a display and/or speaker for user feedback. The pressure pad provides the structural member on which the accelerometer (and housing) is supported. Neither the accelerometer nor force sensor of the pad are essential to detecting chest release, as other sensors can be used. The force sensor can measure force or pressure.

[0037] The accelerometer housing can be shaped similar to a hockey puck and can rest either directly on the patient's sternum or on the pad or other structural member. Preferably the accelerometer is positioned to be over the victim's sternum in the position recommended for chest compressions. A force sensor can be placed below (as shown) or above the accelerometer housing. The rescuer presses on the accelerometer housing (or pressure pad) to perform chest compressions. The accelerometer senses the motion of the chest during CPR and the force sensor measures the force or pressure applied. The AED supplies power to the sensors and digitizes the electrical signals coming from the accelerometer and force sensor. Based on previous calibrations of the sensors, the accelerometer signal is integrated to determine the housing displacement, and the output of the force sensor is converted to standard pressure or force units.

[0038] FIG. 2 shows a sample drawing of the signals recorded during CPR using the implementation of FIG. 1. The acceleration signal is band pass filtered and integrated to derive displacement information (e.g., a displacement signal). Compressions (C1-C5) can be detected from the displacement signal. The compression rate is calculated from the interval between compressions (e.g. (time of C2 - time of C1)), and compression depth is measured from the compression onset to peak displacement (e.g. (d1 - d0)). The onset and peak compression values are saved for each compression. The pressures at the compression onset and offset are used to determine the force used to achieve a given compression depth. The compliance of the chest can be estimated from the compression displacement and the related compression pressure. The pressure "p0" is the reference pressure prior to the start of CPR and is related to the resting chest displacement "d0". The pressure "p1" is the pressure required to achieve the displacement "d1". The chest compliance is estimated from the following equation:

$$\text{Chest Compliance} = |(d1 - d0) / (p1 - p0)|$$

[0039] Where d1 is the displacement at the peak of the compression, d0 is the displacement at the onset of the compression, p1 is the pressure at the peak of the compression, and p0 is the pressure at the onset of the compression. The chest compliance can be calculated for each compression and averaged to improve the measurement accuracy.

[0040] Once the patient specific chest compliance is known, it can be used to estimate the absolute displacement of the puck when combined with the instantaneous puck pressure measure from the following equation:

$$\text{Displacement} = \text{compliance} * (p - p0)$$

[0041] Where p is the pressure measured from the puck at a point in time, p0 is the resting puck pressure when there is no compressions or handling by the rescuer. Therefore, the chest release displacement can be estimated by the following equation:

$$\text{Displacement at the release of chest} = \text{compliance} * (p3 - p0).$$

[0042] Where compliance is determined as described above, p3 is the chest release pressure (estimated as the onset pressure of the next compression), and p0 is the resting pressure.

[0043] The chest release pressure can alternately be measured as the minimum pressure point between the two compressions.

[0044] The chest release displacement point is compared to a pre-defined threshold level to determine if the chest was substantially released between two compressions (i.e., released sufficiently to create a pressure in the chest that facilitates venous filling of the heart). A combination of voice prompts and display messages can be used to tell the rescuer to more completely release the chest between compressions if the chest release displacement point does not return below the set threshold. The chest release displacement value can be averaged to improve the estimate accuracy. The comparison to the threshold level could also be done via "voting" logic such as the last x out of y values exceed the set threshold and trigger the release of chest feedback. The CPR release of chest algorithm continually runs while the rescuer performs CPR and provides immediate feedback if the rescuer does not release the chest at any time during the resuscitation.

[0045] Although not necessary, the threshold level is preferably adjusted dynamically as a function of the calculated chest compliance. For patients with a lower compliance, the threshold can be increased since increased force will have little or no effect on displacement. For patients with higher compliance, the threshold may need to be decreased.

[0046] The calculated estimate of chest compliance can also be used with the output of the force sensor to estimate the depth of chest compression. Thus, for example, the output of the accelerometer could be used with the output of the force sensor during an initial time interval to calculate an estimate of chest compliance. Thereafter, the estimated chest compliance could be used to convert the force measurement into an estimated depth of chest compression.

[0047] FIG. 3 shows another implementation wherein the force sensor is replaced with a mechanical or electrical switch. The rescuer performs CPR by pressing on the switch/housing assembly. The switch is activated based on the forces used with CPR compressions and deactivated when a compression is released. The switch may provide for bistable positional states such as in a domed switch that when depressed would provide tactile feedback to the hand of the rescuer upon the start of the compression (dome collapse) and at the end of compression (dome return). The switch vibration associated with the transition between the two states may also be sufficient to provide an audible feedback to the rescuer as well. If the compression release vibration is heard and/or felt, the chest can be considered by the rescuer to have been released.

[0048] FIG. 4 shows the acceleration, derived displacement, and switch output signals during a sample of CPR. Each compression is identified at the top of the diagram (C1 - C5). The compression interval, rate, and depth are measured from the acceleration signal. The dashed line overlaying the switch output curve indicated the force on the puck assembly and is drawn to show the actuation of the switch when the force curve exceeds that activation threshold (solid straight line). Time t1 shows the actuation of the switch and time t2 shows the release of the switch. On the third compression (C3), the compression switches (ON) at time t3, but does not switch off at time t4 because the force on the chest does not go below the trigger treshold. The acceleration signal shows that chest compressions are continuing, but the switch indicates that the chest is not being substantially released. When chest release is not occcuring, the AED can audibly and/or visually prompt the user to release the chest.

[0049] In another implementation, the acceleration waveform alone is analyzed without the use of a switch or force sensor. FIG. 5 depicts the acceleration, velocity and displacement for a single compression/decompression cycle. The input signal from the acceleration sensor, as shown in the block diagram in FIG. 6, is conditioned and filtered to minimized

artifact and noise and is input to an A/D converter. The A/D converter is then read by the micropocessor. In FIG. 5, the points of interest in the acceleration waveform are as follows:

1. A0 is the point of maximum acceleration during the compression downstroke.
2. A-2 is the compensatory small upstroke that rescuers often do just prior to the initiation of the compression downstroke and marks the initiation point of the compression downstroke.
3. A-1 is the point of maximum acceleration of the compression downstroke.
4. A1 is the point of maximum deceleration on the decompression upstroke.
5. A2 is a small upward release when the rescuer's hands are slightly lifted from the patient's sternum during an optimum compression cycle.
6. A-3 and A3 are inflection points where the signal deviates from baseline.
7. SA0 and SA1 are the slopes of the acceleration of the line segments on each side of A0.
8. SVO andSV1 are the slopes of the line segments (- acceleration) as shown on the velocity curve.
9. VMax is the maximum velocity achieved during the compression downstroke.

[0050] Many algorithms can be used for determination of substantial release of the chest. One algorithm is as follows:

1. Determine fiducial point A0. Completion of the compression determination should approach real time in order to provide maximum benefit to the rescuer. Delays of approximately 1-4 seconds are acceptable and will limit the types of 'search forward' algorithms that can be implemented. A0 can be detected by a number of means. One method is to band pass filter the acceleration signal to produce maximum output signal amplitude of signals having a slope most closely approximating those observed in real compression signals. The band pass output is then input to a threshold detection function. If the signal amplitude is larger than the threshold, then SA0 has been detected. The threshold itself may be dynamically adjusted in amplitude to minimize susceptibility to noise and interference. For instance, if out of band noise such as 60 Hz interference is detected, then the threshold may be increased. The threshold may also be gradually lowered following an SA0 detection such that the probability of detection is increased for signals that occur at the expected interval and is decreasing for false signals that may occur immediately subsequent to the detection. Once SA0 has been detected, the algorithm can search forward until it finds the peak amplitude, A0.
2. Searching backwards and forwards from point A0, the points A-3, A-2, A-1, A0, A1, A2 and A3 can be determined.
3. The acceleration signal can then be decomposed into constituent triangles formed from these fiducial points. TriangleA0 refers to the triangle formed by the A-1, A0 and A1 fiducial points (in gray in FIG. 5.).
4. The triangles are then parameterized using such morphological characteristics as width, amplitude, area, center of mass, skewness, height/width ratio, etc.
5. Area ratios are then calculated for the various triangle pairs. For example the ratio of the areas of TriangleA0 and TriangleA1 , Acceleration Triangular Area Ratio(0,1) [TARA(0,1)]

$$\text{TARA(0,1)} = [\text{Area TriangleA0}] \ / \ [\text{Area of TriangleA1}]$$

6. Amplitude ratios are then calculated for the various triangle pairs. Degree of skew is incorporated into the amplitude calculation by incorporating either skewness or center of mass into the calculation for each triangle. For example the ratio of the areas of TriangleA0 and TriangleA1 , Triangular Amplitude ratioA(0,1) (TAMPRA(0,1))

$$\text{TAMPRA(0,1)} = [\text{Amplitude of TriangleA0}] \ / \ [\text{Amplitude of TriangleA1}]$$

7. The same process is repeated for the triangular width ratio (TWR).
8. A rescuer who applies too much downward force during the decompression upstroke will cause incomplete decompression. This downward force opposes the natural elastic force of the thoracic cage and as a result causes a decreased amplitude and elongation of triangleA1 and triangleA2 as shown in FIG. 7.
9. The acceleration signal is integrated beginning at inflection point A-3 and ending just subsequent to A3 in order to calculate the velocity. The same analysis is used to calculate the fiducial points V-2, VMax, V0 and V1, as well as TAR, TAMPR and TWRs for the velocity curve.
10. The velocity curve segment is integrated a second time to calculate displacement. Displacement values D-3 and D3 and DMax are calculated. Differential displacement, ΔD = D-3 - D3 is calculated.

11. Based on DMax , the device can prompt the rescuer if the depth of compressions are not sufficient.
12. Based on VMax , the user can be prompted to deliver a 'sharper' more rapid pulse to improve hemodynamics.
13. End tidal carbon dioxide (EtCO2) measurements are taken during the course of CPR. Visual and/or audible prompting from the device can encourage the rescuer to increase rate and depth of compressions to improve hemodynamics.
14. The calculated parameters of width, amplitude, area, center of mass, skewness, height/width ratio, TAR, TAMPR and TWR for both the acceleration and the velocity as well as ΔD are used to make a decision on whether the chest was released. The methods used may be standard decision logic (IF-THEN-ELSE) or may involve methods such as fuzzy-logic decision methodology or statistical estimation such as Bayesian methods. In general, ΔD alone would not be used to determine chest release, but nonetheless the signal processing methods have made it possible with this method to be able to measure ΔD without the use of switches or force sensors.
15. Final determination of compression release can be withheld for a number of compression cycles to measure longer term trending of the parameters. For example, the rescuer may have momentarily had to pause to wipe their brow.

[0051] Alternatively, other signal detection and classification methods known to those skilled in the art may be used to determine the relevant morphological features such as those shown in FIG. 7 (CPR with substantial chest release is shown by solid lines; inadequate chest release, by dashed line).

[0052] In another implementation, a velocity sensor is used to determine the motion parameters. One of many possible techniques for sensing velocity is to use magnetic induction to generate a voltage proportional to the relative velocity between a magnet and coil. The configuration is shown in FIG. 8. The magnet may take the form of a permanent magnet, but preferably it is an electromagnet. As shown in FIG. 9A and 9B, a defibrillation pad is placed on the left thorax and another defibrillation pad is placed on the victim's back in the left scapular area. These are optimal locations for defibrillation and provide a good placement to generate magnetic flux changes proportional to sternal displacement. The coils are incorporated directly into the outer edge of each of the defibrillation electrodes. Alternatively, if the desired electrode position is anterior/anterior with both electrodes on the front of the chest, a separate backboard panel may be supplied which is placed under the patient and contains the receiving coil. The use of an electromagnet serves two main purposes: it can be used to calibrate the setup after the electrodes have been applied to the patient and they can be used to provide a synchronous modulation/demodulation of the signal to improve accuracy and minimize susceptibility to noise and artifact.

[0053] The defibrillation electrodes can be constructed with a conventional configuration. An electrically conductive sheet of material that delivers defibrillation current to the patient is backed with an insulating thin foam material, and a slightly adhesive conductive gel coupling agent adheres the conductive sheet to the patient's skin. The foam backing also forms an approximately 0.5 to 1.0 inch border around the active conductive area. The magnetic coil element can be added onto the foam backing and becomes part of the border area, as shown in FIG. 10.

[0054] The device (e.g., AED) can be provided with circuitry for determining whether or not the electrodes have been properly applied to the patient. The method currently employed by most manufacturers of defibrillators is to use a small amplitude, high frequency signal (~2 microamps, 60 KHz) to measure impedance. The electrodes are determined to be applied when the impedance falls into the physiologic range.

[0055] When the device has detected the application of the electrodes, the device can prompt the rescuer to stand clear. At this time, the device will perform calibration of the velocity sensor. A time-varying signal, typically a ramp or sine wave of several frequencies of interest, such as the modulation frequency, is applied to the electromagnet and the signal is measured at the receiving coil. From this, gain and offset coefficients can be calculated for use during the CPR event. This calibration step allows for improved accuracy with patients of varying chest sizes and in the presence of any nearby magnetically conductive surfaces or objects.

[0056] Preferably, a synchronous detector can be employed to minimize susceptibility to noise and artifact as shown in the block diagram in FIG. 11. A sine wave carrier frequency of 500 Hz or more is supplied to the electromagnet coil to generate an oscillating magnetic field that, in turn, induces a voltage on the receiving coil. Chest compressions vary the field intensity at the receiving coil, thus causing an amplitude modulation of the carrier. As can be seen in FIG. 11, a band pass filter immediately subsequent to signal reception reduces interference outside the range of the carrier frequency such as AC magnetic interference. The phase lock loop (PLL) is used for carrier regeneration, but since the transmitter and receiver are in the same device, the transmission carrier can be used for detection as well, as long as circuitry is provided for phase adjustment of the demodulation signal. Multiplexer S1, combined with the demodulation signal, causes rectification of the signal, which can then be low pass filtered to recover the compression velocity waveform. Alternatively, a synchronous AM demodulator can be employed with an analog multiplier stage.

[0057] In another implementation, the velocity signal may then be used to reduce artifacts in the ECG signal. This is accomplished by first time-aligning the ECG and velocity signal by such methods as cross-correlation techniques known to those skilled in the art. This will provide alignment of the two signals relative to the compressions. Then, preferably,

adaptive filtering methods are used such as those involved in the minimization of the mean-squared error between the ECG and the velocity.

[0058] In a further implementation, more sophisticated signal processing methods may be used to minimize ECG artifacts induced by CPR chest compressions. For example, methods known as feed forward active noise cancellation (FANC) may be used. FIG. 12 shows a block diagram of the filtered-X least mean squares (FXLMS ANC) algorithm, as developed by Widrow and Burgess. P(z) represents the unknown plant through which the signal x(n) is filtered. Digital filter W(z) is adaptively adjusted to minimize the error signal e(n). In one implementation, as depicted in FIG. 13, x(n) is the unfiltered ECG signal, P(z) is eliminated from the diagram, and d(n) is approximated with the chest compression velocity signal v(n). In the LMS algorithm, assuming a mean square cost function $\xi(n) = E[e2(n)]$, the adaptive filter minimizes the instantaneous squared error, $\xi(n) = e2(n)$, using the steepest descent algorithm, which updates the coefficient vector in the negative gradient direction with step size μ:

$$w(n + 1) = w(n) - \mu/2 * \tilde{N}\,\xi(n),$$

where $\tilde{N}\xi(n)$ is an instantaneous estimate of the mean square error (MSE) gradient at time n equal to -2v(n) e(n). Stability and accuracy of the FXLMS ANC algorithm by adding a variable cutoff low pass filter H(z) to eliminate frequency components in the ECG not related to the chest compression artifact. In general, the spectral energy of the chest compression artifact is predominately lower than those of the ECG. A cutoff frequency of approximately 3 Hz is adequate in many cases, but this may vary from patient to patient and among different rescuers performing chest compressions. To overcome this difficulty, an FFT is performed on v(n) and input into a cutoff frequency estimation (CFE) procedure that determines the optimal cutoff frequency, fC, for the lowpass filter. In a preferred implementation, the decision is based on calculating the frequency, not to exceed 5Hz, below which 80% of the waveform energy is present, but this percentage may vary and additional decision logic may be employed. For instance, an FFT may also be calculated for x(n), also input to the CFE procedure. By first normalizing amplitude of the frequency spectra X(z) amplitude peak of the compression artifact and then subtracting the velocity spectra V(z) from the normalized input X'(z), the difference spectra is calculated $\Delta X'(z) = X'(z) - V'(z)$. Frequencies are then determined for V(z) and $\Delta X'(z)$ at which most of the spectral energy is within, set in this embodiment to 97%, and labeled fCV and fCX, respectively, and shown in FIG 14. FC is then set to the lesser of fCV and fCX. Alternatively, fC can be set to some intermediate frequency between fCV and fCX.

[0059] A simpler though related implementation is shown in FIG. 15, in which the CFE procedure is used to calculate the cutoff frequency for a high pass filter. Using the same methods as described in the previous paragraph, an FFT is performed on v(n) and input into a cutoff frequency estimation (CFE) procedure that determines the optimal cutoff frequency, fC, for, in this case, a high pass filter. In the preferred embodiment, the decision is based on calculating the frequency, not to exceed 5 Hz, below which 80% of the waveform energy is present, but this percentage may vary and additional decision logic may be employed. An FFT may also be calculated for x(n), and also input to the CFE procedure and the optimal high pass cutoff frequency can be determined by the methods described in the previous paragraph. For instances when the spectral energy of the compression artifact is distinct from the ECG signal, this method will have a performance equivalent to the FXLMS just described; its performance will be somewhat inferior when the spectra of the ECG and compression artifact overlap, however.

[0060] Many other implementations of the invention other than those described above are within the invention, which is defined by the following claims. For example, it is not necessary that the invention include an external defibrillator, as a device for assisting delivery of CPR could be provided without defibrillation capability. The CPR assistance device could even be a pocket device that is for assisting with manual delivery of CPR.

[0061] Features of the one aspect of the invention may not be required in implementations of other aspects of the invention. For example, it is not necessary in some implementations of the invention that chest compliance be determined, or that substantial release of the chest be determined, or that a particular type of sensor (e.g., accelerometer, force sensor, velocity sensor), or combination of sensors, be used, or that there be analysis of features of a motion waveform, or that maximum velocity be estimated, or that artifacts in detected ECG signals be reduced.

Claims

1. Apparatus for assisting a rescuer in performing chest compressions during CPR on a victim, the apparatus comprising:

   a pad or other structure configured to be applied to the chest near or at the location at which the rescuer applies

force to produce the chest compressions;
at least one sensor connected to the pad, the sensor being configured to sense movement of the chest;
processing circuitry for processing the output of the sensor to determine whether the rescuer is substantially releasing the chest following chest compressions; and
at least one prompting element connected to the processing circuitry for providing the rescuer with a visual or auditory prompt indicating whether the chest is not being sufficiently released following chest compressions.

2. The apparatus of claim 1 wherein the pad or other structure is a pad to which force is applied by rescuer.

3. The apparatus of claim 1 wherein the sensor includes an accelerometer.

4. The apparatus of claim 1 wherein the sensor includes a force sensor.

5. The apparatus of claim 1 wherein the sensor includes a velocity sensor.

6. The apparatus of claim 1 wherein the sensor includes both a force sensor and an accelerometer or velocity sensor.

7. The apparatus of claim 1 wherein the prompting element includes a speaker for delivering an audible prompt to the rescuer.

8. The apparatus of claim 1 wherein the prompting element includes a display for delivering a visual prompt to the rescuer.

9. The apparatus of claim 1 wherein the apparatus is part of an external defibrillator.

10. The apparatus of claim 9 wherein the external defibrillator is an AED.

11. The apparatus of claim 1 wherein the processing circuitry includes a digital processor executing software.

12. The apparatus of claim 1 wherein the processing circuitry is adapted to determining whether the rescuer is substantially releasing the chest by analyzing motion of the chest.

13. The apparatus of claim 12 wherein the processing circuitry is further adapted to analyze motion of the chest comprising analyzing features or the shape of a waveform representing chest motion.

14. The apparatus of claim 1 wherein the sensor comprises both a sensor to sense movement of the chest and a sensor to sense force applied to the chest, and wherein the processing circuitry uses outputs of both sensors to provide information representative of chest compliance.

15. The apparatus of claim 14 wherein processing circuitry is adapted to use the information of chest compliance to determine a level of applied pressure/force that corresponds to a substantial release of the chest.

16. The apparatus of claim 5 further comprising processing circuitry for processing the output of the velocity sensor to estimate the displacement of the chest.

17. The apparatus of claim 16 wherein the processing circuitry has the capability to integrate an output of the velocity sensor.

18. The apparatus of claim 5 or 28 wherein the velocity sensor is configured to be located approximately adjacent to the location at which the body is compressed.

19. The apparatus of claim 5 or 28 the velocity sensor is configured to be positioned to sense the relative velocity between opposite surfaces of the chest.

20. The apparatus of claim 5 or 28 wherein the velocity sensor comprises a conductor and a magnet, and velocity is sensed by sensing the current induced in the conductor by relative motion between the conductor and the magnets

21. The apparatus of claim 20 wherein the magnet comprises one of a permanent magnet and an electromagnet.

22. The apparatus of claim 20 wherein the conductor and magnet are positioned on opposite surfaces of the chest.

23. The apparatus of claim 20 wherein the conductor comprises a coil that is unitary with a defibrillation electrode pad.

24. The apparatus of claim 20 wherein the conductor and magnet each comprise a coil that is unitary with a defibrillation electrode pad.

25. The apparatus of claim 5 or 28 wherein the magnet comprises an electromagnet and the electromagnet produces a magnetic field that oscillates at a frequency greater than 1 KHz, and further comprising coil detection circuitry to which the coil is connected, wherein the coil detection circuitry is capable of synchronously demodulating the detected signal to reduce susceptibility to drift and noise.

26. The apparatus of claim 5 or 28 further comprising circuitry for acquiring ECG signals from the victim, and wherein the processing circuitry has the capability to process the output of the velocity sensor and the ECG signals to reduce ECG artifacts from chest compressions by use of velocity sensor output.

27. The apparatus of claim 1 wherein the sensor comprises
at least one motion sensor connected to the pad and the processing circuitry is configured for processing the output of the motion sensor to estimate the maximum velocity of compression of the chest; and
at least one prompting device connected to the processing circuitry is configured for providing the rescuer with information representative of the maximum velocity of compression.

28. The apparatus of claim 27 wherein the motion sensor comprises a velocity sensor.

29. The apparatus of claim 1 wherein the sensor comprises
a motion sensor for applying to the chest of a patient at a location near or at the location at which a rescuer plies force to produce chest compressions, and the processing circuitry is configured for determining chest displacement from analysis of features of the motion waveform produced by the motion sensor.

30. The apparatus of claim 29 wherein the motion sensor is a velocity sensor.

31. The apparatus of claim 29 wherein the motion sensor is an accelerometer.

32. The apparatus of claim 31 wherein the processing circuitry is configured for deciding from the analysis of features of the acceleration waveform whether or not a rescuer has sufficiently released the patient's chest.

33. The apparatus of claim 31 wherein the processing circuitry is configured for processing the output of the accelerometer to provide velocity and acceleration waveforms.

34. The apparatus of claim 32 wherein the processing circuitry is configured for processing the output of the accelerometer to provide velocity and acceleration waveforms, and analyzing the velocity and acceleration waveforms to determine whether or not a rescuer has sufficiently released the patient's chest.

35. The apparatus of claim 33 wherein the analysis of velocity waveforms includes determining the maximal velocity of compression:

36. The apparatus of claim 31 or 33 wherein determining chest displacement from analysis of features comprises determining onset and completion times for a compression cycle from the features of the waveforms.

37. The apparatus of claim 36 wherein determining chest displacement further comprises integrating the acceleration waveform over a time segment defined by the onset and completion times.

38. The apparatus of claim 31 or 33 wherein the processing circuitry is configured for analyzing the features of the upstroke portion of the waveforms to determine whether there has been sufficient release of the chest.

39. The apparatus of claim 31 or 33 wherein the processing circuitry is configured for generating promts for prompting a rescuer based as to whether compressions are within desired limits on compression depth and compression release.

40. The apparatus of claim 39 wherein the prompts to the rescuer are based on multicycle trends, so that they are not immediately influenced by the rescuer taking a brief break in the application of CPR.

41. The apparatus of claim 39 wherein the processing circuitry is configured for determining chest compliance, and using the determined chest compliance to adjust the level of pressure/force that the rescuer is permitted to apply at the end of a compression stroke without being prompted as to insufficiently releasing the chest.

42. The apparatus of claim 33 wherein the features determined from the waveforms include one or more of the following: width, amplitude, area, center of mass, skewness, height/width ratio, TAR, TAMPR and TWR.

43. The apparatus of claim 42 wherein the features are used by the processing circuitry to make a decision as to whether the chest of the victim has been sufficiently released.

44. The apparatus of claim 43 wherein decisions are made using either standard decision logic, fuzzy-logic decision methodology, or statistical estimation.

45. The apparatus of claim 1 where the processing circuitry is further configured for
detecting ECG signals during application of chest compressions;
processing the output of the sensor to determine information on the velocity of chest compressions; and
using the information on the velocity to reduce at least one signal artifact in the ECG signal resulting from the chest compressions.

46. The apparatus of claim 45 wherein the sensor is a velocity sensor, and the information on the velocity is determined from the velocity sensor.

47. The apparatus of claim 45 wherein the sensor is an accelerometer, and the information on the velocity is determined from integration of the output of the accelerometer.

48. The apparatus of claim 45 wherein using the information on the velocity to reduce at least one signal artifact in the ECG signal comprises time aligning the ECG signals with the velocity.

49. The apparatus of claim 45 wherein using the information on the velocity to reduce at least one signal artifact in the ECG signal comprises an adaptive filter that is adjusted to remove chest compression artifacts.

50. The apparatus of claim 45 wherein using the information on the velocity to reduce at least one signal artifact in the ECG signal comprises feed forward active noise cancellation.

51. The apparatus of claim 45 wherein using the information on the velocity to reduce at least one signal artifact in the ECG signal comprises determining a cutoff frequency for a filter that separates the ECG signal from chest compression artifacts.

52. The apparatus of claim 1 wherein the sensor comprises
at least one motion sensor connected to the pad, the motion sensor being configured to sense movement of the chest, wherein the apparatus further comprises
at least one force sensor connected to the pad, the force sensor being configured to sense force applied to the chest, and wherein
the processing circuitry is configured for processing the output of the motion sensor and force sensor to estimate the compliance of the chest.

53. The apparatus of claim 52 wherein the estimated compliance and the output of the force sensor are used to determine the depth of compression of the chest.

54. The apparatus of claim 53 wherein the motion sensor is an accelerometer, and the output of the accelerometer is used primarily for estimating chest compliance, and compression depth during CPR is estimated by using the estimated compliance to convert the output of the force sensor into estimated compression depth.

55. The apparatus of claim 54 wherein the output of the accelerometer is used during limited time intervals for estimating chest compliance, and outside of those limited time intervals chest compression is determined from the estimated

compliance and the output of the force sensor without substantial use of the output of the accelerometer.

56. The apparatus of claim 52 or 53 wherein the estimated compliance and the output of the force sensor are used to determine whether the chest has been substantially released.

Patentansprüche

1. Apparat zur Unterstützung eines Retters beim Durchführen des Pressens des Brustkorbs während einer kardiopulmonalen Wiederbelebung (CPR) an einem Opfer, wobei der Apparat folgendes umfasst:

ein Polster oder eine andere Struktur, das bzw. die derart gestaltet ist, an dem Brustkorb in der Nähe oder an der Stelle, an der der Retter Kraft anwendet, um ein Pressen des Brustkorbs zu erzeugen, angewendet zu werden;
mindestens einen Sensor, der mit dem Polster verbunden ist, wobei der Sensor derart gestaltet ist, die Bewegung des Brustkorbs zu erkennen;
eine Verarbeitungsschaltung *(processing circuitry)* zur Weiterverarbeitung der Ausgabe des Sensors, um zu ermitteln, ob der Retter nach dem Pressen des Brustkorbs den Brustkorb wesentlich entlastet; und
mindestens ein Aufforderungselement, das mit der Verarbeitungsschaltung verbunden ist, um dem Retter ein visuelles oder hörbares Aufforderungszeichen zur Verfügung zu stellen, das anzeigt, ob der Brustkorb nach dem Pressen des Brustkorbs nicht genügend entlastet wurde.

2. Apparat nach Anspruch 1, wobei das Polster oder die andere Struktur ein Polster ist, auf das durch den Retter Kraft angewendet wird.

3. Apparat nach Anspruch 1, wobei der Sensor einen Beschleunigungsmesser beinhaltet.

4. Apparat nach Anspruch 1, wobei der Sensor einen Kraftsensor beinhaltet.

5. Apparat nach Anspruch 1, wobei der Sensor einen Geschwindigkeitssensor beinhaltet.

6. Apparat nach Anspruch 1, wobei der Sensor sowohl einen Kraftsensor als auch einen Beschleunigungsmesser oder einen Geschwindigkeitssensor beinhaltet.

7. Apparat nach Anspruch 1, wobei das Aufforderungselement einen Lautsprecher beinhaltet, um dem Retter ein hörbares Aufforderungszeichen zu liefern.

8. Apparat nach Anspruch 1, wobei das Aufforderungselement eine Anzeige beinhaltet, um dem Retter ein visuelles Aufforderungszeichen zu liefern.

9. Apparat nach Anspruch 1, wobei der Apparat ein Teil eines externen Defibrillators ist.

10. Apparat nach Anspruch 9, wobei der externe Defibrillator ein AED ist.

11. Apparat nach Anspruch 1, wobei die Verarbeitungsschaltung eine digitale, Prozessor ausführende Software beinhaltet.

12. Apparat nach Anspruch 1, wobei die Verarbeitungsschaltung angepasst ist, durch Analyse der Bewegung des Brustkorbs zu ermitteln, ob der Retter wesentlich den Brustkorb entlastet.

13. Apparat nach Anspruch 12, wobei die Verarbeitungsschaltung ferner angepasst ist, die Bewegung des Brustkorbs zu analysieren, umfassend Analysemerkmale oder die Form einer Wellenform, die die Bewegung des Brustkorbs darstellt.

14. Apparat nach Anspruch 1, wobei der Sensor sowohl einen Sensor zum Erkennen der Bewegung des Brustkorbs als auch einen Sensor zum Erkennen der auf den Brustkorb angewendeten Kraft umfasst, und wobei die Verarbeitungsschaltung die Ausgaben von beiden Sensoren verwendet, um Informationen zur Verfügung zu stellen, die repräsentativ für die Nachgiebigkeit des Brustkorbs sind.

15. Apparat nach Anspruch 14, wobei die Verarbeitungsschaltung angepasst ist, die Informationen zu verwenden, die repräsentativ für die Nachgiebigkeit des Brustkorbs sind, um einen Grad des angewendeten Drucks / der angewendeten Kraft zu ermitteln, der einer wesentlichen Entlastung des Brustkorbs entspricht.

16. Apparat nach Anspruch 5, der ferner eine Verarbeitungsschaltung zum Weiterverarbeiten der Ausgabe des Geschwindigkeitssensors umfasst, um die Verlagerung des Brustkorbs abzuschätzen.

17. Apparat nach Anspruch 16, wobei die Verarbeitungsschaltung in der Lage ist, eine Ausgabe des Geschwindigkeitssensors zu integrieren.

18. Apparat nach Anspruch 5 oder 28, wobei der Geschwindigkeitssensor derart gestaltet ist, dass er ungefähr angrenzend zu der Stelle, an der der Körper zusammengepresst wird, angeordnet werden kann.

19. Apparat nach Anspruch 5 oder 28, wobei der Geschwindigkeitssensor derart gestaltet ist, dass er positioniert werden kann, um die relative Geschwindigkeit zwischen den gegenüberliegenden Oberflächen des Brustkorbs zu erkennen.

20. Apparat nach Anspruch 5 oder 28, wobei der Geschwindigkeitssensor einen Leiter und einen Magneten umfasst, und die Geschwindigkeit durch Erkennen des induzierten Stroms in dem Leiter durch die relative Bewegung zwischen dem Leiter und dem Magneten erkannt wird.

21. Apparat nach Anspruch 20, wobei der Magnet einen von einem Permanentmagneten und einem Elektromagneten umfasst.

22. Apparat nach Anspruch 20, wobei der Leiter und der Magnet auf gegenüberliegenden Oberflächen des Brustkorbs positioniert sind.

23. Apparat nach Anspruch 20, wobei der Leiter eine Spule umfasst, die einheitlich mit einem Defibrillationselektrodenpolster ist.

24. Apparat nach Anspruch 20, wobei der Leiter und der Magnet jeweils eine Spule umfassen, die einheitlich mit einem Defibrillationselektrodenpolster ist.

25. Apparat nach Anspruch 5 oder 28, wobei der Magnet einen Elektromagneten umfasst und der Elektromagnet ein magnetisches Feld erzeugt, das bei einer Frequenz größer als 1 kHz oszilliert, und ferner eine Spulendetektionsschaltung umfasst, mit der die Spule verbunden ist, wobei die Spulendetektionsschaltung in der Lage ist, das detektierte Signal synchron zu demodulieren, um die Anfälligkeit gegenüber Drift und Rauschen zu reduzieren.

26. Apparat nach Anspruch 5 oder 28, der ferner eine Schaltung zum Erlangen von ECG-Signalen von dem Opfer umfasst und wobei die Verarbeitungsschaltung in der Lage ist, den Ausgang des Geschwindigkeitssensors und der ECG-Signale weiterzuverarbeiten, um ECG-Artefakte durch Pressen des Brustkorbs zu reduzieren, unter Verwendung des Geschwindigkeitssensorausgangs.

27. Apparat nach Anspruch 1, wobei der Sensor folgendes umfasst:

mindestens einen Bewegungssensor, der mit dem Polster verbunden ist;
und die Verarbeitungsschaltung gestaltet ist zum Weiterverarbeiten des Ausgangs des Bewegungssensors, um die maximale Geschwindigkeit des Pressens des Brustkorbs abzuschätzen; und
mindestens ein Aufforderungsgerät, das mit der Verarbeitungsschaltung verbunden ist, und das derart gestaltet ist, dass es dem Retter Informationen zur Verfügung stellt, die repräsentativ für die maximale Geschwindigkeit des Pressens sind.

28. Apparat nach Anspruch 27, wobei der Bewegungssensor einen Geschwindigkeitssensor umfasst.

29. Apparat nach Anspruch 1, wobei der Sensor einen Bewegungssensor umfasst zum Anwenden an dem Brustkorb eines Patienten an einer Stelle in der Nähe oder an der Stelle, an der der Retter Kraft anwendet, um ein Pressen des Brustkorbs zu erzeugen, und die Verarbeitungsschaltung gestaltet ist zum Ermitteln der Brustkorbverlagerung aus der Analyse der Merkmale der Bewegungswellenform, die durch den Bewegungssensor erzeugt wird.

30. Apparat nach Anspruch 29, wobei der Bewegungssensor ein Geschwindigkeitssensor ist.

31. Apparat nach Anspruch 29, wobei der Bewegungssensor ein Beschleunigungsmesser ist.

32. Apparat nach Anspruch 31, wobei die Verarbeitungsschaltung gestaltet ist zum Entscheiden aus der Analyse der Merkmale der Beschleunigungswellenform, ob oder ob nicht ein Retter den Brustkorb des Patienten genügend entlastet hat.

33. Apparat nach Anspruch 31, wobei die Verarbeitungsschaltung gestaltet ist für das Weiterverarbeiten des Ausgangs des Beschleunigungsmessers, um Geschwindigkeits- und Beschleunigungswellenformen zur Verfügung zu stellen.

34. Apparat nach Anspruch 32, wobei die Verarbeitungsschaltung gestaltet ist für das Weiterverarbeiten des Ausgangs des Beschleunigungsmessers, um Geschwindigkeits- und Beschleunigungswellenformen zur Verfügung zu stellen, und das Analysieren der Geschwindigkeits- und Beschleunigungswellenformen, um zu ermitteln, ob oder ob nicht ein Retter den Brustkorb des Patienten genügend entlastet hat.

35. Apparat nach Anspruch 33, wobei die Analyse der Geschwindigkeitswellenformen eine Ermittlung der maximalen Geschwindigkeit des Pressens beinhaltet.

36. Apparat nach Anspruch 31 oder 33, wobei die Ermittlung der Brustkorbverlagerung aus der Analyse der Merkmale die Ermittlung der Anfangs- und Abschlusszeiten für einen Presszyklus aus den Merkmalen der Wellenformen umfasst.

37. Apparat nach Anspruch 36, wobei die Ermittlung der Brustkorbverlagerung ferner das Integrieren der Beschleunigungswellenform über einen Zeitabschnitt umfasst, der durch die Anfangs- und Abschlusszeiten definiert ist.

38. Apparat nach Anspruch 31 oder 33, wobei die Verarbeitungsschaltung gestaltet ist für das Analysieren der Merkmale des aufwärtigen Teils der Wellenformen, um zu ermitteln, ob der Brustkorb genügend entlastet wurde.

39. Apparat nach Anspruch 31 oder 33, wobei die Verärbeitungsschaltung gestaltet ist zum Erzeugen von Aufforderungszeichen zum Auffordern eines Retters auf der Basis, ob das Pressen innerhalb gewünschter Grenzen der Presstiefe und Pressentlastung ist.

40. Apparat nach Anspruch 39, wobei die Aufforderungszeichen an den Retter auf Trends nach mehrfachen Zyklen basieren, so dass sie nicht unmittelbar **dadurch** beeinflusst werden, wenn der Retter eine kurze Pause bei der Anwendung der CPR macht.

41. Apparat nach Anspruch 39, wobei die Verarbeitungsschaltung gestaltet ist für das Ermitteln der Brustkorbnachgiebigkeit und das Verwenden der ermittelten Brustkorbnachgiebigkeit, um den Grad des Drucks / der Kraft anzupassen, die der Retter anwenden darf am Ende einer Presseinheit, ohne aufgefordert zu werden, dass er den Brustkorb ungenügend entlastet.

42. Apparat nach Anspruch 33, wobei die Merkmale, die aus den Wellenformen ermittelt wurden, eines oder mehrere der folgenden umfassen: Breite, Amplitude, Fläche, Massenmittelpunkt, Schräge, Verhältnis der Höhe zur Breite, TAR, TAMPR und TWR.

43. Apparat nach Anspruch 42, wobei die Merkmale durch die Verarbeitungsschaltung verwendet werden, um eine Entscheidung zu treffen, ob der Brustkorb des Opfers genügend entlastet wurde.

44. Apparat nach Anspruch 43, wobei die Entscheidungen unter Verwendung von entweder Standardentscheidungslogik, Fuzzy-Logik-Entscheidungsmethodik oder statistischer Abschätzung getroffen werden.

45. Apparat nach Anspruch 1, wobei die Verarbeitungsschaltung ferner gestaltet ist zum
Ermitteln von ECG-Signalen während der Anwendung des Pressens des Brustkorbs;
Weiterverarbeiten des Ausgangs des Sensors, um Informationen über die Geschwindigkeit des Pressens des Brustkorbs zu ermitteln; und
Verwenden der Informationen über die Geschwindigkeit, um mindestens ein Signalartefakt in dem ECG-Signal, das sich aus dem Pressen des Brustkorbs ergibt, zu reduzieren.

46. Apparat nach Anspruch 45, wobei der Sensor ein Geschwindigkeitssensor ist und die Informationen über die Geschwindigkeit durch den Geschwindigkeitssensor ermittelt werden.

47. Apparat nach Anspruch 45, wobei der Sensor ein Beschleunigungsmesser ist und die Informationen über die Geschwindigkeit durch Integration des Ausgangs des Beschleunigungsmessers ermittelt werden.

48. Apparat nach Anspruch 45, wobei die Verwendung der Informationen über die Geschwindigkeit, um mindestens ein Signalartefakt in dem ECG-Signal zu reduzieren, einen Zeitabgleich der ECG-Signale mit der Geschwindigkeit umfasst.

49. Apparat nach Anspruch 45, wobei die Verwendung der Informationen über die Geschwindigkeit, um mindestens ein Signalartefakt in dem ECG-Signal zu reduzieren, einen anpassungsfähigen Filter umfasst, der so eingestellt ist, dass Brustkorbpressartefakte entfernt werden.

50. Apparat nach Anspruch 45, wobei die Verwendung der Informationen über die Geschwindigkeit, um mindestens ein Signalartefakt in dem ECG-Signal zu reduzieren, eine Vorwärtssteuerung der aktiven Rauschlöschung umfasst.

51. Apparat nach Anspruch 45, wobei die Verwendung der Informationen über die Geschwindigkeit, um mindestens ein Signalartefakt in dem ECG-Signal zu reduzieren, die Ermittlung einer Abschaltfrequenz für einen Filter umfasst, der das ECG-Signal von den Brustkorbpressartefakten abtrennt.

52. Apparat nach Anspruch 1, wobei der Sensor folgendes umfasst:

mindestens einen Bewegungssensor, der mit dem Polster verbunden ist, wobei der Bewegungssensor derart gestaltet ist, die Bewegung des Brustkorbs zu erkennen,
wobei der Apparat ferner umfasst
mindestens einen Kraftsensor, der mit dem Polster verbunden ist, wobei der Kraftsensor derart gestaltet ist, die auf den Brustkorb angewendete Kraft zu erkennen, und wobei
die Verarbeitungsschaltung gestaltet ist zum Weiterverarbeiten des Ausgangs des Bewegungssensors und des Kraftsensors, um die Nachgiebigkeit des Brustkorbs abzuschätzen.

53. Apparat nach Anspruch 52, wobei die geschätzte Nachgiebigkeit und der Ausgang des Kraftsensors verwendet werden, um die Tiefe des Pressens des Brustkorbs zu ermitteln.

54. Apparat nach Anspruch 53, wobei der Bewegungssensor ein Beschleunigungsmesser ist, und der Ausgang des Beschleunigungsmessers primär zum Abschätzen der Brustkorbnachgiebigkeit verwendet wird, und die Presstiefe während der CPR unter Verwendung der geschätzten Nachgiebigkeit abgeschätzt wird, um den Ausgang des Kraftsensors in eine geschätzte Presstiefe umzuwandeln.

55. Apparat nach Anspruch 54, wobei der Ausgang des Beschleunigungsmessers während begrenzter Zeitintervalle zum Abschätzen der Brustkorbnachgiebigkeit verwendet wird, und außerhalb dieser begrenzten Zeitintervalle die Brustkorbkompression durch die geschätzte Nachgiebigkeit und den Ausgang des Kraftsensors ohne wesentliche Verwendung des Ausgangs des Beschleunigungsmessers ermittelt wird.

56. Apparat nach Anspruch 52 oder 53, wobei die geschätzte Nachgiebigkeit und der Ausgang des Kraftsensors verwendet werden, um zu ermitteln, ob der Brustkorb wesentlich entlastet wurde.

Revendications

1. Dispositif pour aider un secouriste à effectuer des compressions thoraciques pendant une réanimation cardio-respiratoire sur une victime, le dispositif comprenant :

un coussinet ou une autre structure configuré pour être appliqué à la poitrine à proximité de ou à l'emplacement auquel le secouriste applique une force pour produire les compressions thoraciques ;
au moins un capteur connecté au coussinet, le capteur étant configuré pour détecter le mouvement de la poitrine ;
des éléments de circuit de traitement pour traiter la sortie du capteur pour déterminer si le secouriste relâche ou non sensiblement la poitrine à la suite des compressions thoraciques ; et

au moins un élément d'incitation connecté aux éléments de circuit de traitement pour fournir au secouriste une incitation visuelle ou auditive indiquant si la poitrine n'est pas suffisamment relâchée à la suite des compressions thoraciques.

2. Dispositif selon la revendication 1, dans lequel le coussinet ou l'autre structure est un coussinet auquel une force est appliquée par un secouriste.

3. Dispositif selon la revendication 1, dans lequel le capteur comprend un accéléromètre.

4. Dispositif selon la revendication 1, dans lequel le capteur comprend un capteur de force.

5. Dispositif selon la revendication 1, dans lequel le capteur comprend un capteur de vitesse.

6. Dispositif selon la revendication 1, dans lequel le capteur comprend à la fois un capteur de force et un accéléromètre ou un capteur de vitesse.

7. Dispositif selon la revendication 1, dans lequel l'élément d'incitation comprend un haut-parleur pour délivrer une incitation audible au secouriste.

8. Dispositif selon la revendication 1, dans lequel l'élément d'incitation comprend un afficheur pour délivrer une incitation visuelle au secouriste.

9. Dispositif selon la revendication 1, dans lequel le dispositif est une partie d'un défibrillateur externe.

10. Dispositif selon la revendication 9, dans lequel le défibrillateur externe est un AED.

11. Dispositif selon la revendication 1, dans lequel les éléments de circuit de traitement comprennent un processeur numérique exécutant un logiciel.

12. Dispositif selon la revendication 1, dans lequel les éléments de circuit de traitement sont adaptés pour déterminer si le secouriste relâche sensiblement la poitrine en analysant le mouvement de la poitrine.

13. Dispositif selon la revendication 12, dans lequel les éléments de circuit de traitement sont en outre adaptés pour analyser le mouvement de la poitrine comprenant l'analyse des caractéristiques ou de la forme d'une forme d'onde représentant le mouvement de la poitrine.

14. Dispositif selon la revendication 1, dans lequel le capteur comprend à la fois un capteur pour détecter le mouvement de la poitrine et un capteur pour détecter une force appliquée à la poitrine, et dans lequel les éléments de circuit de traitement utilisent les sorties des deux capteurs pour fournir des informations représentatives de la souplesse de la poitrine.

15. Dispositif selon la revendication 14, dans lequel les éléments de circuit de traitement sont adaptés pour utiliser les informations représentatives de la souplesse de la poitrine pour déterminer un niveau de pression/force appliquée qui correspond à un relâchement significatif de la poitrine.

16. Dispositif selon la revendication 5 comprenant en outre des éléments de circuit de traitement pour traiter la sortie du capteur de vitesse pour estimer le déplacement de la poitrine.

17. Dispositif selon la revendication 16, dans lequel les éléments de circuit de traitement ont la capacité d'intégrer une sortie du capteur de vitesse.

18. Dispositif selon la revendication 5 ou 28, dans lequel le capteur de vitesse est configuré pour être situé approximativement adjacent à l'emplacement auquel le corps est comprimé.

19. Dispositif selon la revendication 5 ou 28, dans lequel le capteur de vitesse est configuré pour être positionné pour détecter la vitesse relative entre les surfaces opposées de la poitrine.

20. Dispositif selon la revendication 5 ou 28, dans lequel le capteur de vitesse comprend un conducteur et un aimant,

et la vitesse est détectée en détectant le courant induit dans le conducteur par le mouvement relatif entre le conducteur et l'aimant.

21. Dispositif selon la revendication 20, dans lequel l'aimant comprend l'un d'un aimant permanent et d'un électroaimant.

22. Dispositif selon la revendication 20, dans lequel le conducteur et l'aimant sont positionnés sur les surfaces opposées de la poitrine.

23. Dispositif selon la revendication 20, dans lequel le conducteur comprend une bobine qui est d'un seul tenant avec un coussinet d'électrode de défibrillation.

24. Dispositif selon la revendication 20, dans lequel le conducteur et l'aimant comprennent chacun une bobine qui est d'un seul tenant avec un coussinet d'électrode de défibrillation.

25. Dispositif selon la revendication 5 ou 28, dans lequel l'aimant comprend un électroaimant et l'électroaimant produit un champ magnétique qui oscille à une fréquence supérieure à 1 kHz, et comprenant en outre des éléments de circuit de détection de bobine auxquels la bobine est connectée, dans lequel les éléments de circuit de détection de bobine sont capables de démoduler de manière synchrone le signal détecté pour réduire la sensibilité à la dérive et au bruit.

26. Dispositif selon la revendication 5 ou 28, comprenant en outre des éléments de circuit pour acquérir les signaux d'ECG de la victime, et dans lequel les éléments de circuit de traitement ont la capacité de traiter la sortie du capteur de vitesse et les signaux d'ECG pour réduire les artéfacts d'ECG des compressions thoraciques en utilisant la sortie du capteur de vitesse.

27. Dispositif selon la revendication 1, dans lequel le capteur comprend :

au moins un capteur de mouvement connecté au coussinet, et les éléments de circuit de traitement sont configurés pour traiter la sortie du capteur de mouvement pour estimer la vitesse maximum de compression de la poitrine ; et
au moins un dispositif d'incitation connecté aux éléments de circuit de traitement qui est configuré pour fournir au secouriste des informations représentatives de la vitesse maximum de compression.

28. Dispositif selon la revendication 27, dans lequel le capteur de mouvement comprend un capteur de vitesse.

29. Dispositif selon la revendication 1, dans lequel le capteur comprend un capteur de mouvement à appliquer à la poitrine d'un patient à proximité de ou à l'emplacement auquel un secouriste applique une force pour produire des compressions thoraciques, et les éléments de circuit de traitement sont configurés pour déterminer le déplacement de la poitrine à partir de l'analyse des caractéristiques de la forme d'onde de mouvement produite par le capteur de mouvement.

30. Dispositif selon la revendication 29, dans lequel le capteur de mouvement est un capteur de vitesse.

31. Dispositif selon la revendication 29, dans lequel le capteur de mouvement est un accéléromètre.

32. Dispositif selon la revendication 31, dans lequel les éléments de circuit de traitement sont configurés pour décider à partir de l'analyse des caractéristiques de la forme d'onde d'accélération si un secouriste a suffisamment relâché la poitrine du patient.

33. Dispositif selon la revendication 31, dans lequel les éléments de circuit de traitement sont configurés pour traiter la sortie de l'accéléromètre pour fournir des formes d'onde de vitesse et d'accélération.

34. Dispositif selon la revendication 32, dans lequel les éléments de circuit de traitement sont configurés pour traiter la sortie de l'accéléromètre pour fournir des formes d'onde de vitesse et d'accélération, et pour analyser les formes d'onde de vitesse et d'accélération pour déterminer si un secouriste a suffisamment relâché la poitrine du patient.

35. Dispositif selon la revendication 33, dans lequel l'analyse des formes d'onde de vitesse comprend la détermination de la vitesse de compression maximale.

36. Dispositif selon la revendication 31 ou 33, dans lequel la détermination du déplacement de la poitrine à partir de l'analyse des caractéristiques comprend la détermination des instants de début et de fin d'un cycle de compression à partir des caractéristiques des formes d'onde.

37. Dispositif selon la revendication 36, dans lequel la détermination du déplacement de la poitrine comprend en outre l'intégration de la forme d'onde d'accélération sur un segment temporel défini par les instants de début et de fin.

38. Dispositif selon la revendication 31 ou 33, dans lequel les éléments de circuit de traitement sont configurés pour analyser les caractéristiques d'une partie de course ascendante des formes d'onde pour déterminer s'il y a eu un relâchement suffisant de la poitrine.

39. Dispositif selon la revendication 31 ou 33, dans lequel les éléments de circuit de traitement sont configurés pour générer des incitations pour inciter un secouriste selon que les compressions sont ou non dans des limites souhaitées de profondeur de compression et de relâchement de compression.

40. Dispositif selon la revendication 39, dans lequel les incitations du secouriste sont basées sur les tendances de multiples cycles, de sorte qu'elles ne sont pas immédiatement influencées par le fait que le secouriste interrompt brièvement l'application de la réanimation cardio-respiratoire.

41. Dispositif selon la revendication 39, dans lequel les éléments de circuit de traitement sont configurés pour déterminer la souplesse de la poitrine, et pour utiliser la souplesse de la poitrine déterminée pour ajuster le niveau de pression/force que le secouriste est autorisé à appliquer à la fin d'une course de compression sans recevoir d'incitation de relâchement insuffisant de la poitrine.

42. Dispositif selon la revendication 33, dans lequel les caractéristiques déterminées à partir des formes d'onde comprennent un ou plusieurs des éléments suivants : une largeur, une amplitude, une aire, un centre de masse, une inclinaison, un rapport hauteur/largeur, un TAR, un TAMPR et un TWR.

43. Dispositif selon la revendication 42, dans lequel les caractéristiques sont utilisées par les éléments de circuit de traitement pour prendre une décision concernant le fait que la poitrine de la victime a été ou non suffisamment relâchée.

44. Dispositif selon la revendication 43, dans lequel les décisions sont prises en utilisant soit une logique de décision standard, soit une méthodologie de décision à logique floue, soit une estimation statistique.

45. Dispositif selon la revendication 1, dans lequel les éléments de circuit de traitement sont en outre configurés pour détecter les signaux d'ECG pendant l'application de compressions thoraciques ;
traiter la sortie du capteur pour déterminer des informations concernant la vitesse des compressions thoraciques ; et
utiliser les informations concernant la vitesse pour réduire au moins un artéfact de signal dans le signal d'ECG résultant des compressions thoraciques.

46. Dispositif selon la revendication 45, dans lequel le capteur est un capteur de vitesse, et les informations concernant la vitesse sont déterminées à partir du capteur de vitesse.

47. Dispositif selon la revendication 45, dans lequel le capteur est un accéléromètre, et les informations concernant la vitesse sont déterminées à partir de l'intégration de la sortie de l'accéléromètre.

48. Dispositif selon la revendication 45, dans lequel l'utilisation des informations concernant la vitesse pour réduire au moins un artéfact de signal dans le signal d'ECG comprend l'alignement temporel des signaux d'ECG avec la vitesse.

49. Dispositif selon la revendication 45, dans lequel l'utilisation des informations concernant la vitesse pour réduire au moins un artéfact de signal dans le signal d'ECG comprend un filtre adaptatif qui est ajusté pour retirer des artéfacts de compression de poitrine.

50. Dispositif selon la revendication 45, dans lequel l'utilisation des informations concernant la vitesse pour réduire au moins un artéfact de signal dans le signal d'ECG comprend une annulation de bruit active à anticipation.

51. Dispositif selon la revendication 45, dans lequel l'utilisation des informations concernant la vitesse pour réduire au

moins un artéfact de signal dans le signal d'ECG comprend la détermination d'une fréquence de coupure pour un filtre qui sépare le signal d'ECG des artéfacts de compression de poitrine.

52. Dispositif selon la revendication 1, dans lequel le capteur comprend :

au moins un capteur de mouvement connecté au coussinet, le capteur de mouvement étant configuré pour détecter le mouvement de la poitrine, dans lequel le dispositif comprend en outre :

au moins un capteur de force connecté au coussinet, le capteur de force étant configuré pour détecter une force appliquée à la poitrine, et dans lequel
le circuit de traitement est configuré pour traiter les sorties du capteur de mouvement et du capteur de force pour estimer la souplesse de la poitrine.

53. Dispositif selon la revendication 52, dans lequel la souplesse estimée et la sortie du capteur de force sont utilisées pour déterminer la profondeur de compression de la poitrine.

54. Dispositif selon la revendication 53, dans lequel le capteur de mouvement est un accéléromètre, et la sortie de l'accéléromètre est essentiellement utilisée pour estimer la souplesse de la poitrine, et une profondeur de compression pendant une réanimation cardio-respiratoire est estimée en utilisant la souplesse estimée pour convertir la sortie du capteur de force en une profondeur de compression estimée.

55. Dispositif selon la revendication 54, dans lequel la sortie de l'accéléromètre est utilisée pendant des intervalles de temps limités pour estimer la souplesse de la poitrine et, en-dehors de ces intervalles de temps limités, la compression thoracique est déterminée à partir de la souplesse estimée et de la sortie du capteur de force sans utiliser de manière significative la sortie de l'accéléromètre.

56. Dispositif selon la revendication 52 ou 53, dans lequel la souplesse estimée et la sortie du capteur de force sont utilisées pour déterminer si la poitrine a été sensiblement relâchée.

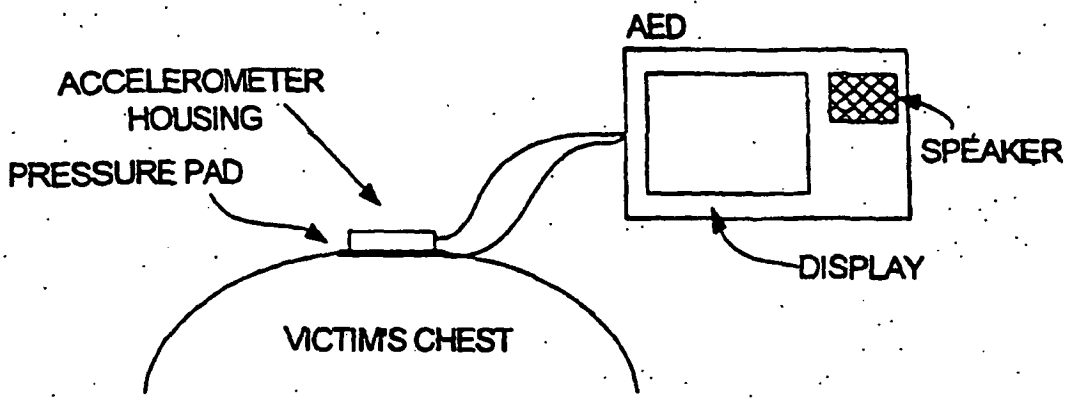
AED
ACCELEROMETER
HOUSING
PRESSURE PAD
SPEAKER
DISPLAY
VICTIM'S CHEST

FIG. 1

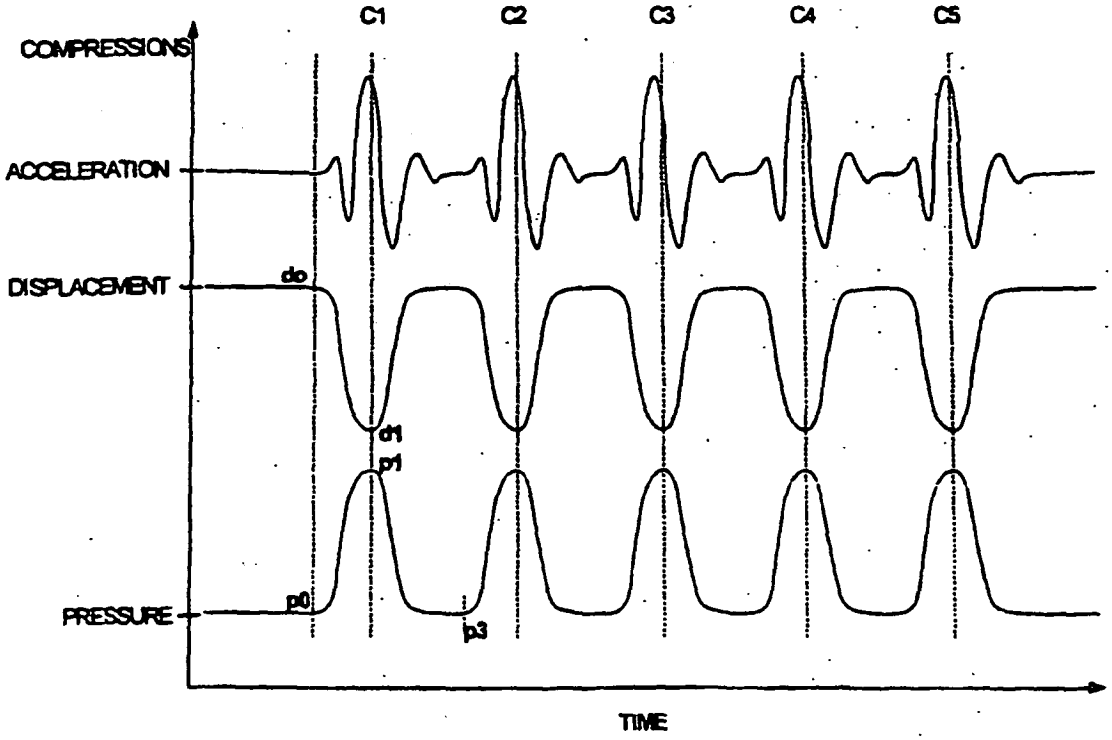
C1
C2
C3
C4
C5
COMPRESSIONS
ACCELERATION
DISPLACEMENT
d0
d1
p1
PRESSURE
p0
p3
TIME

FIG. 2

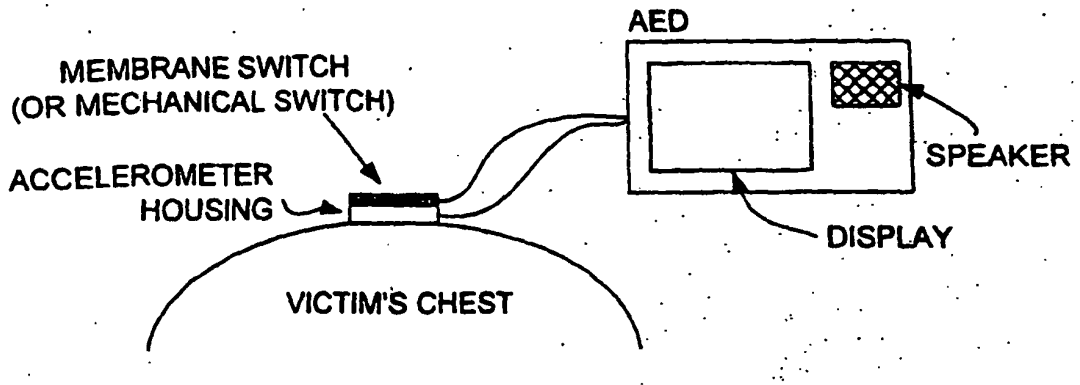
AED
MEMBRANE SWITCH
(OR MECHANICAL SWITCH)
ACCELEROMETER
HOUSING
SPEAKER
DISPLAY
VICTIM'S CHEST

FIG. 3

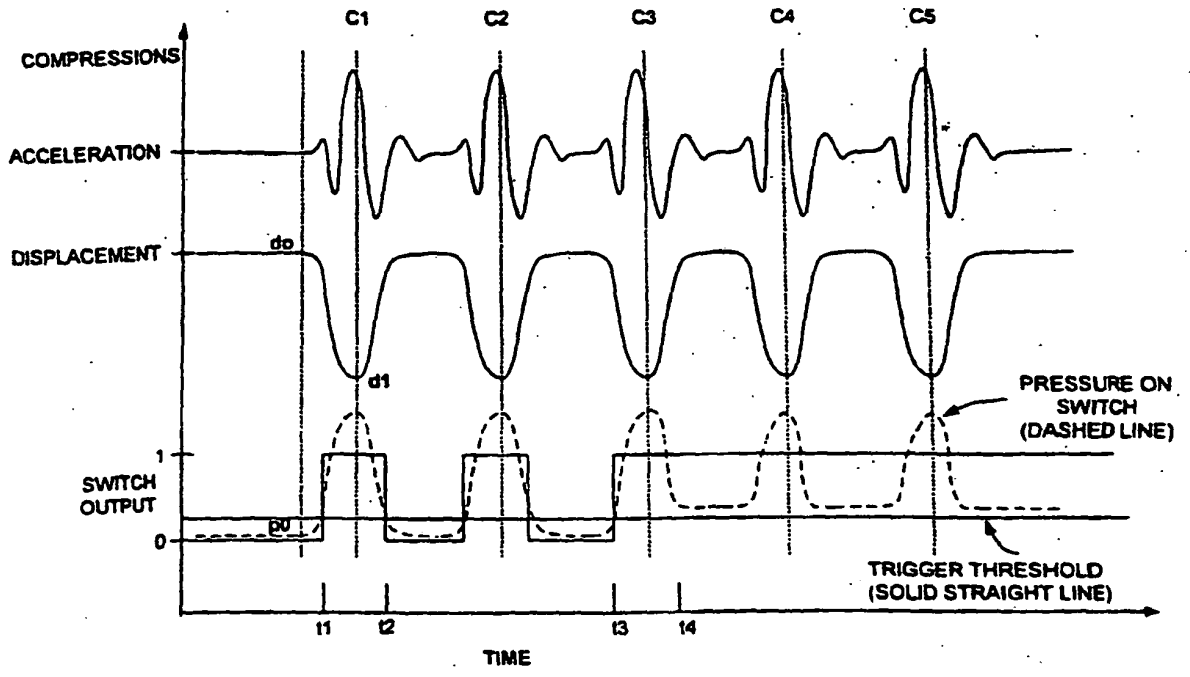
C1
C2
C3
C4
C5
COMPRESSIONS
ACCELERATION
DISPLACEMENT
do
d1
PRESSURE ON
SWITCH
(DASHED LINE)
1
SWITCH
OUTPUT
0
d0
TRIGGER THRESHOLD
(SOLID STRAIGHT LINE)
t1
t2
t3
t4
TIME

FIG. 4

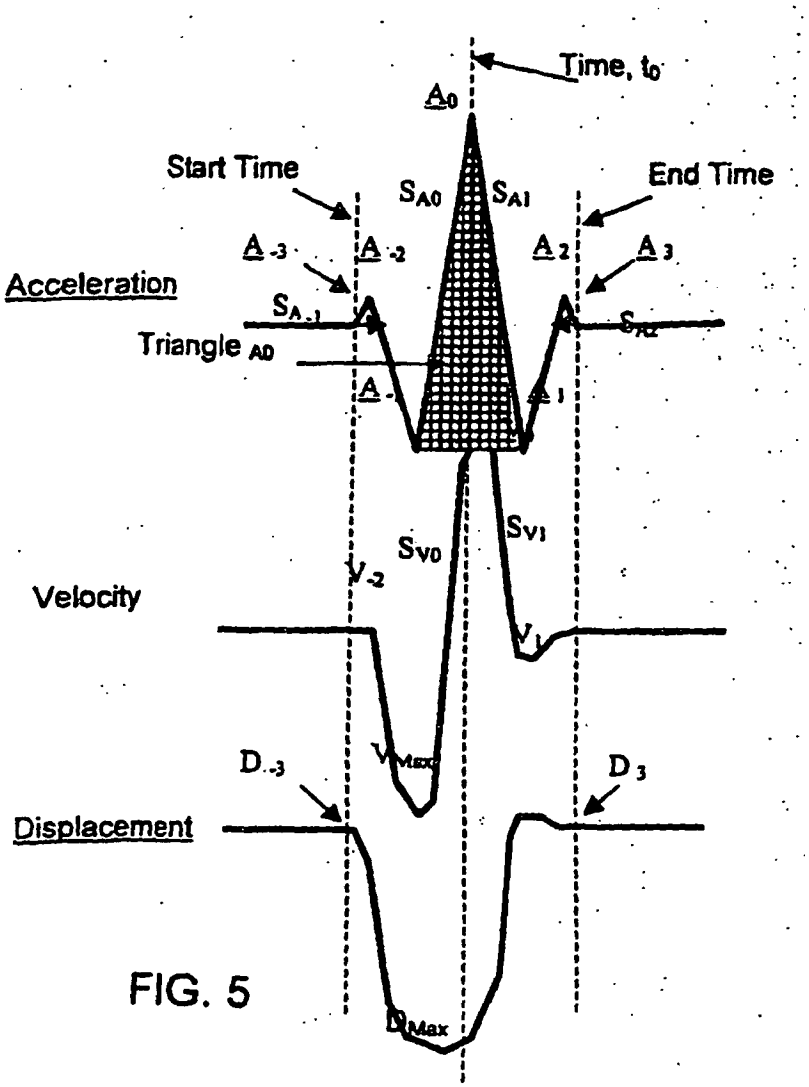
Time, t_0
A_0
Start Time
End Time
S_{A0}
S_{A1}
A_{-3}
A_{-2}
A_2
A_3
Acceleration
S_{A-1}
S_{A2}
Triangle A_0
A_{-1}
A_1
S_{V1}
S_{V0}
V_{-2}
Velocity
V_1
V_{Max}
D_{-3}
D_3
Displacement
D_{Max}

FIG. 5

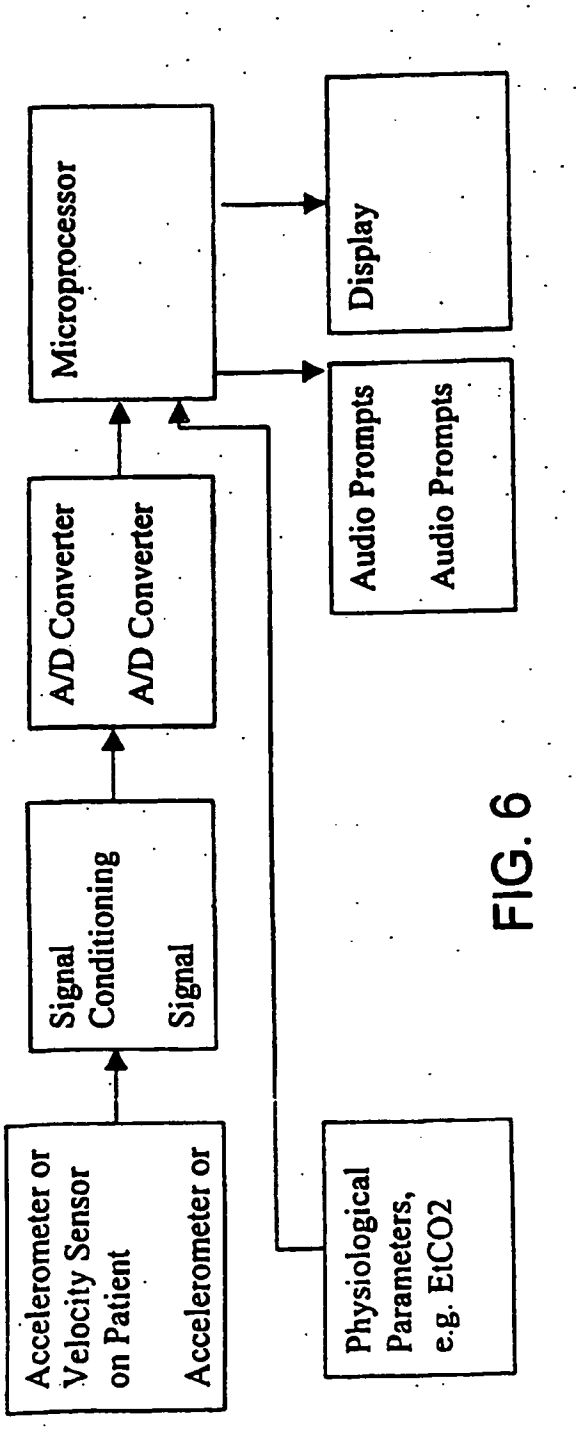
Accelerometer or Velocity Sensor on Patient
Accelerometer or
Signal Conditioning
Signal
A/D Converter
A/D Converter
Microprocessor
Physiological Parameters, e.g. EtCO2
Display
Audio Prompts
Audio Prompts

FIG. 6

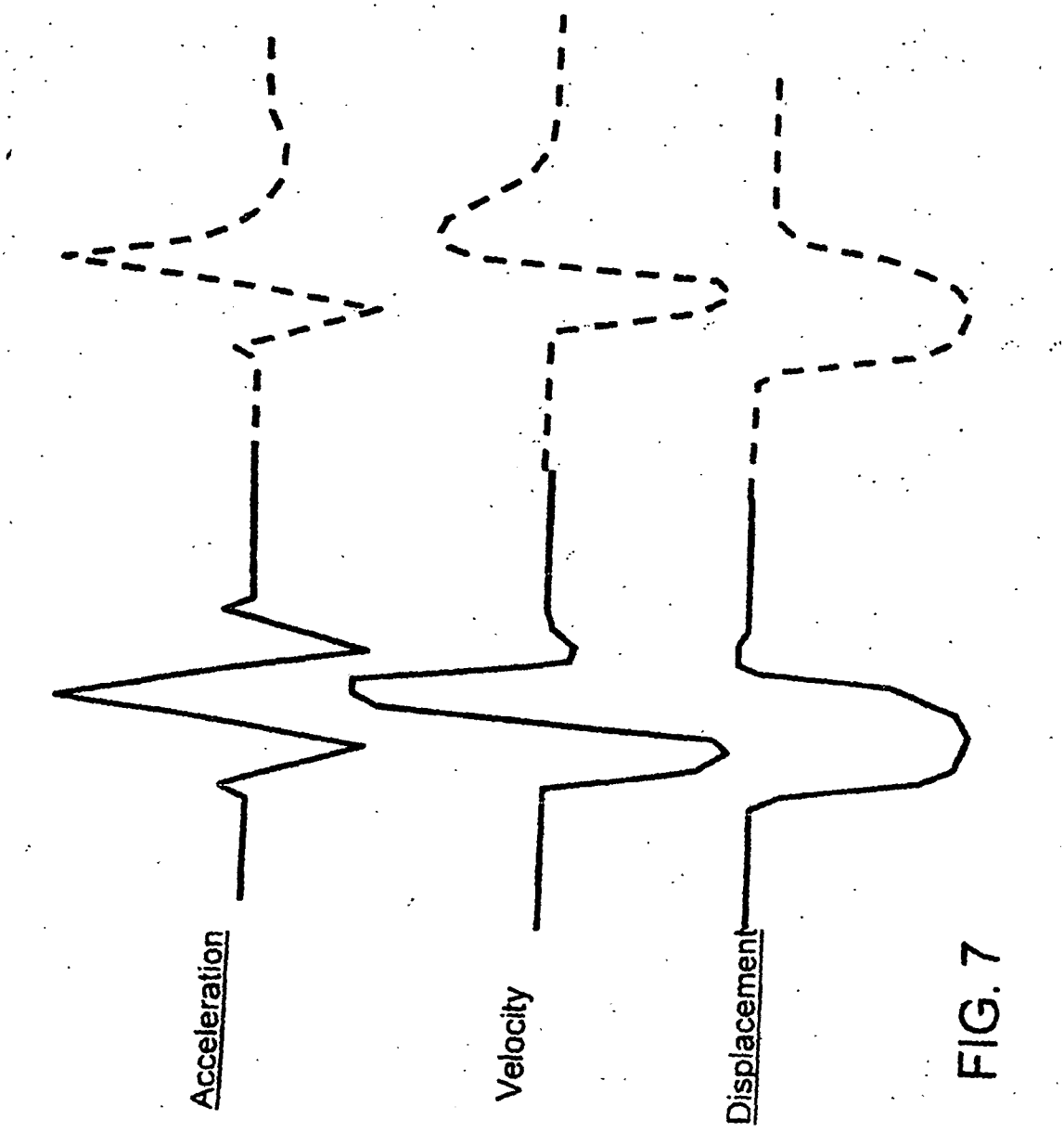

FIG. 7

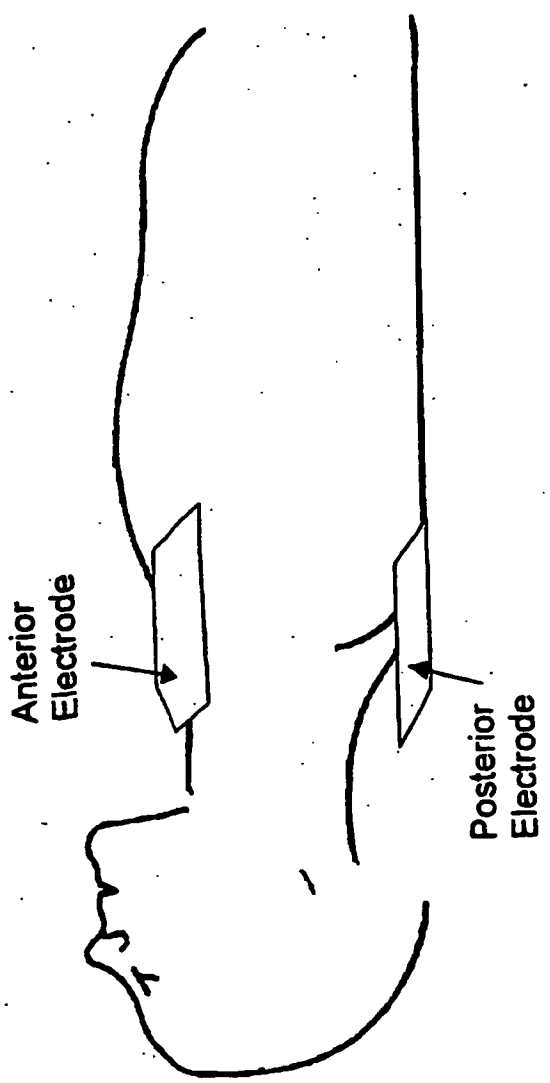

FIG. 8

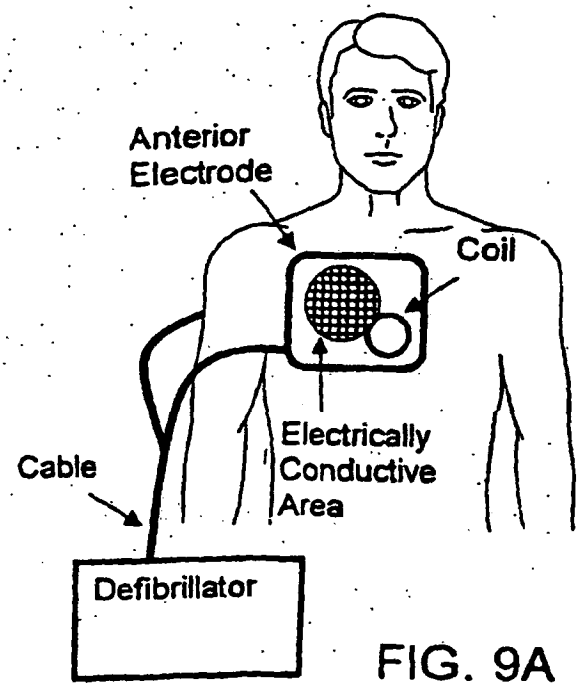

FIG. 9A

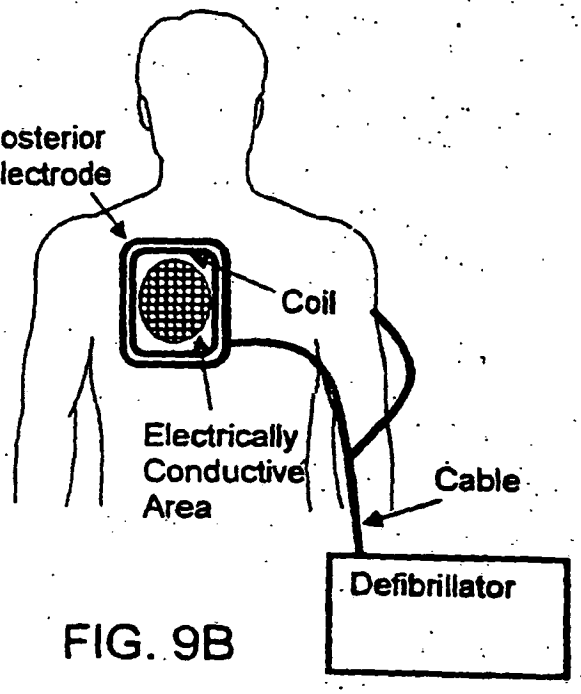

FIG. 9B

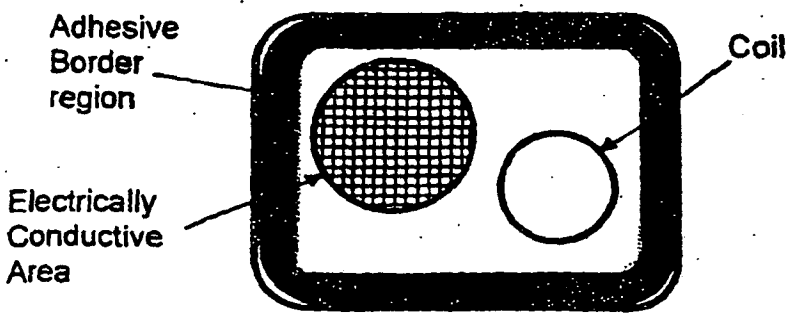

FIG. 10

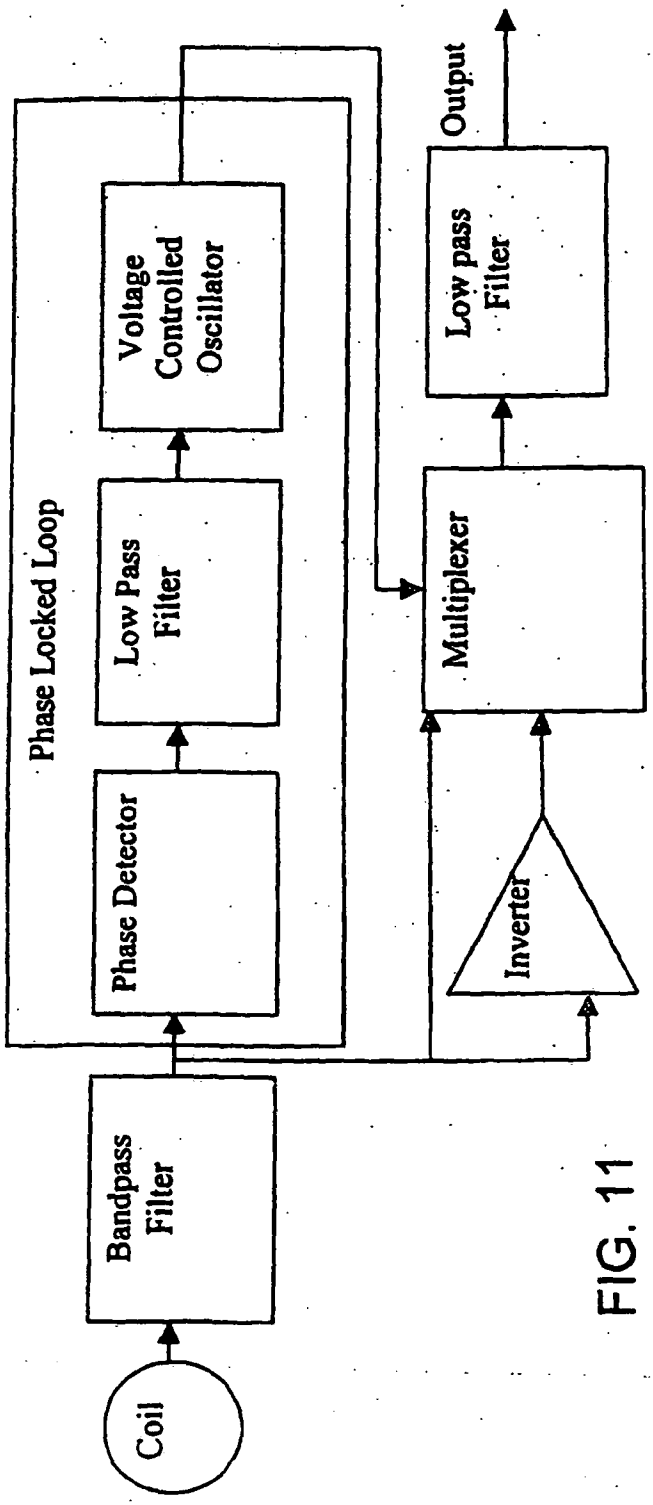
Coil
Bandpass Filter
Phase Locked Loop
Phase Detector
Low Pass Filter
Voltage Controlled Oscillator
Inverter
Multiplexer
Low pass Filter
Output

FIG. 11

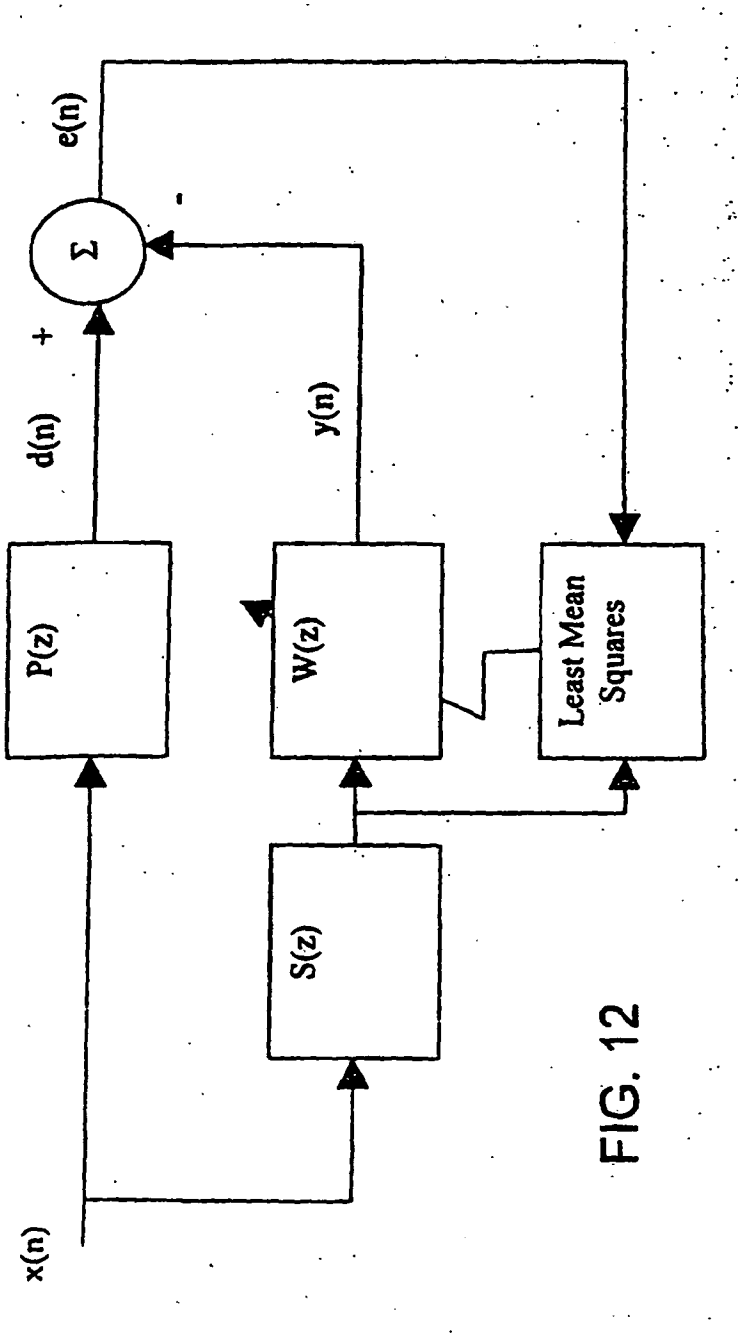

FIG. 12

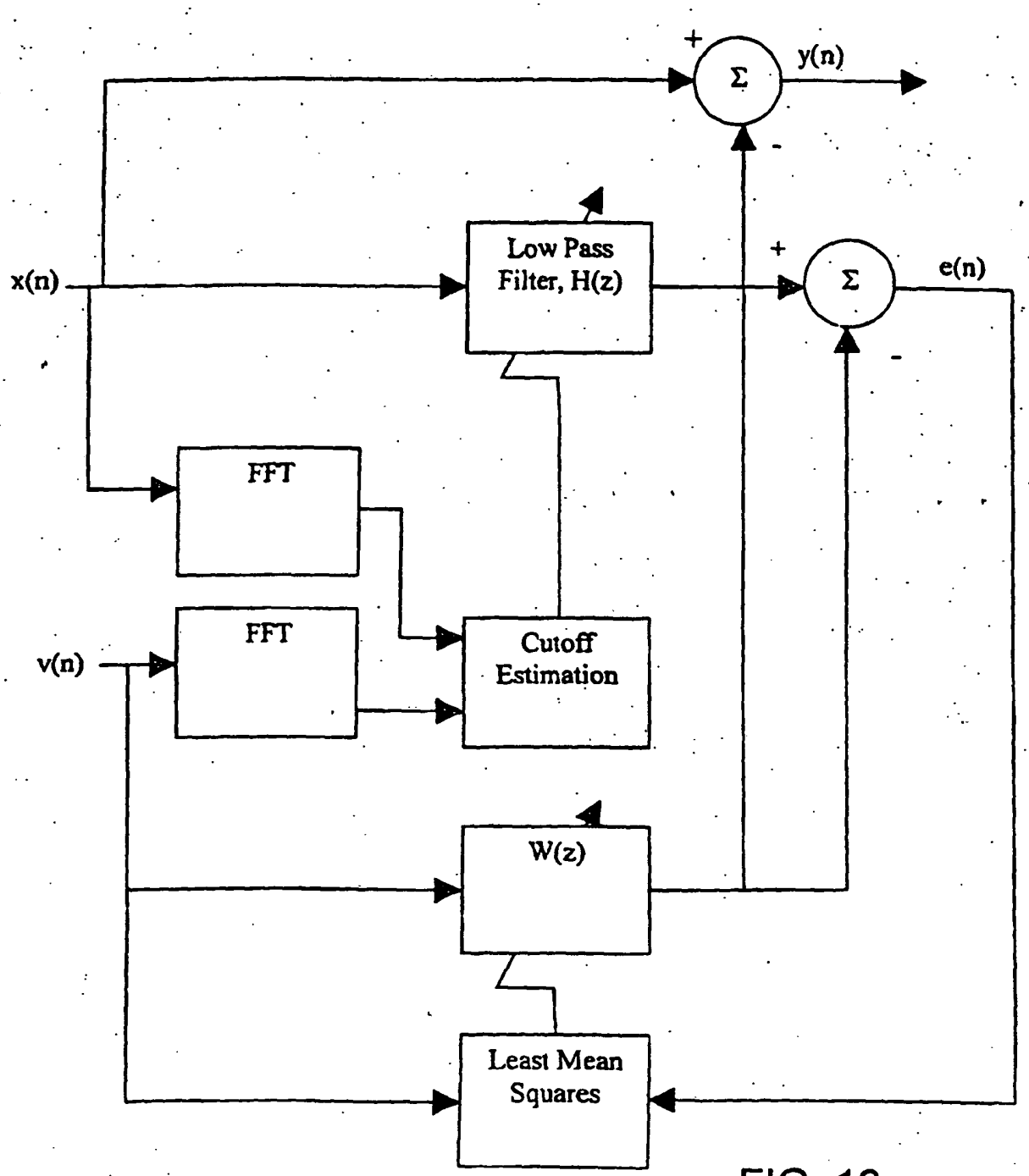
+
Σ
y(n)
-
x(n)
Low Pass
Filter, H(z)
+
Σ
e(n)
-
FFT
FFT
v(n)
Cutoff
Estimation
W(z)
Least Mean
Squares

FIG. 13

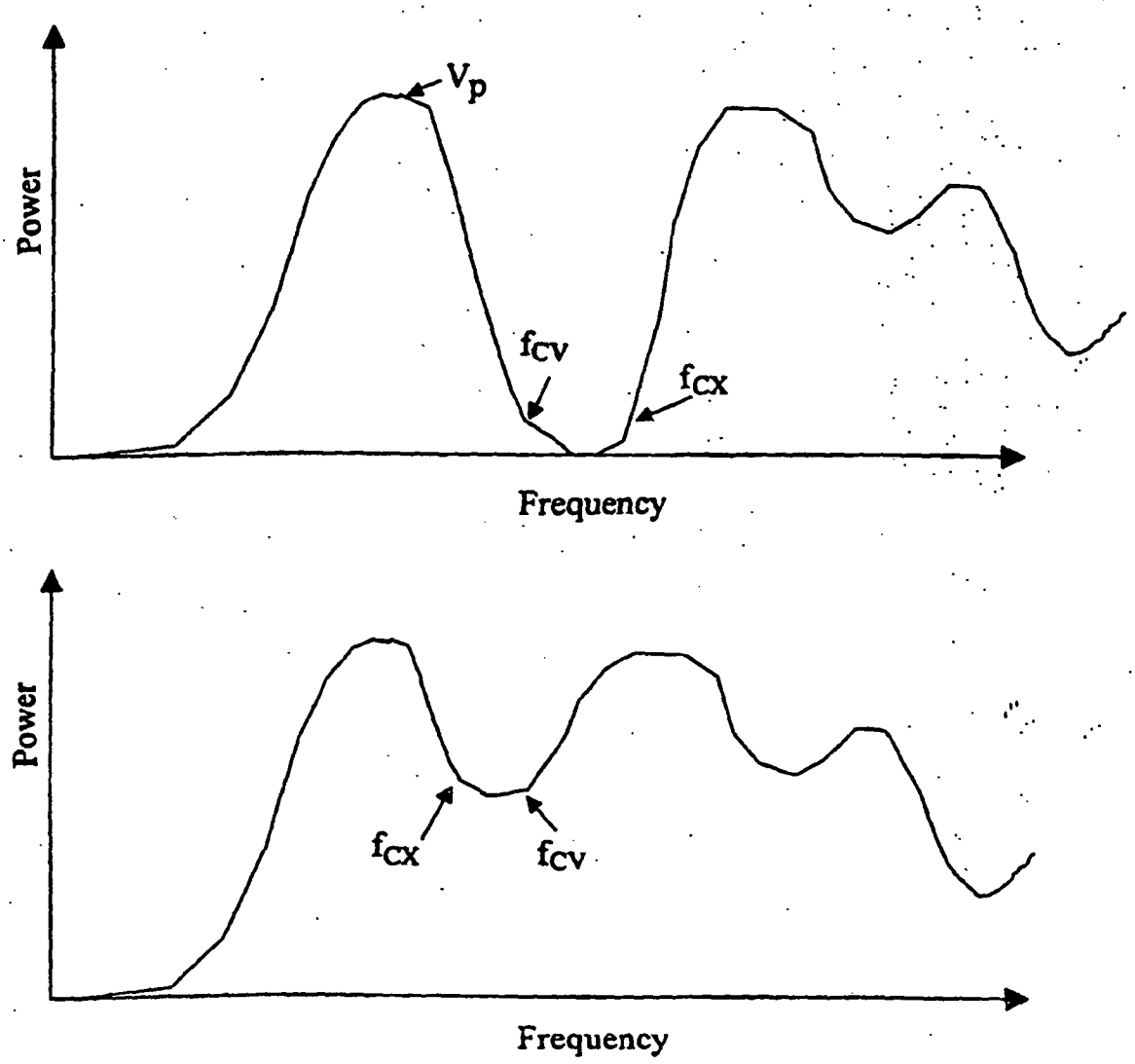

FIG. 14

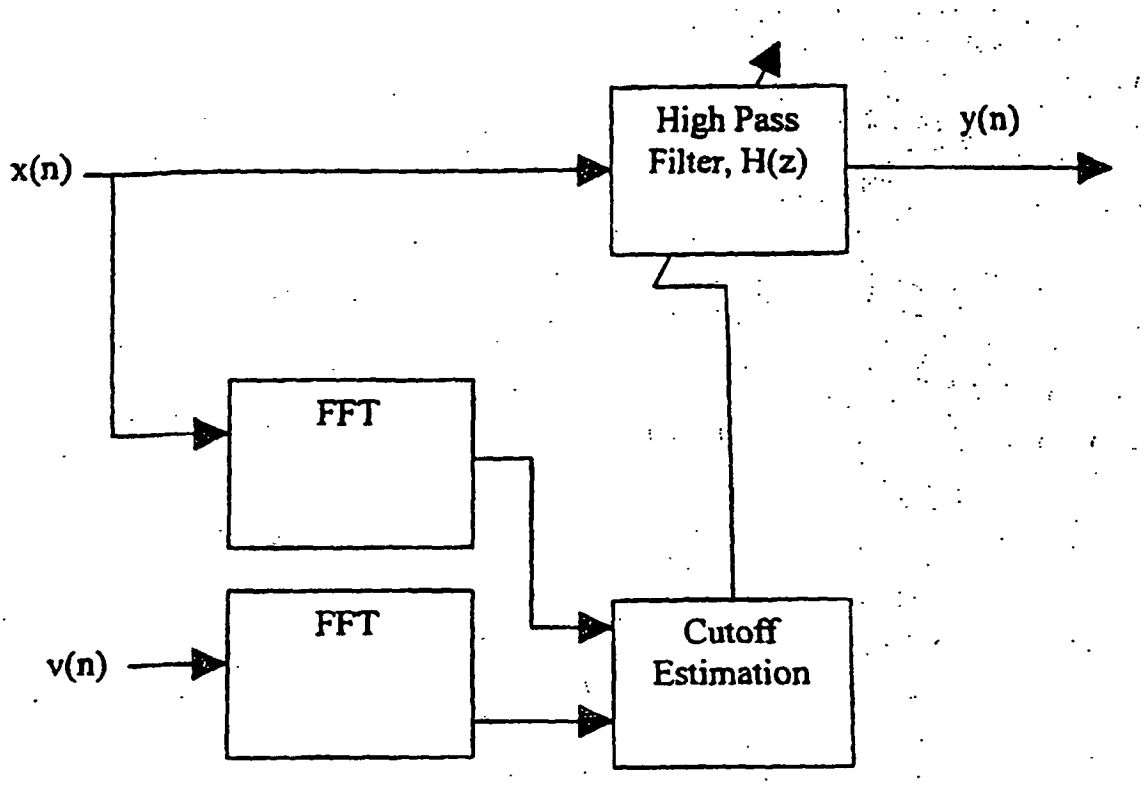

FIG. 15

REFERENCES CITED IN THE DESCRIPTION

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专利名称(译)	在CPR期间增强胸部按压的装置		
公开(公告)号	EP1491176B1	公开(公告)日	2009-06-17
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申请(专利权)人(译)	ZOLL医疗公司		
当前申请(专利权)人(译)	ZOLL医疗公司		
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发明人	GEHEB, FREDERICK BOUCHER, DONALD R. FREEMAN, GARY A.		
IPC分类号	A61H31/00 A61N1/39 G06F19/00 A61B5/0402 A61B5/00 A61B5/024 A61B5/0245 A61B5/11 A61B5/145 A62B9/00 A62B33/00		
CPC分类号	A61B5/024 A61B5/0402 A61B5/11 A61B5/1102 A61B5/145 A61B5/6823 A61B5/6833 A61B5/7455 A61B2562/0219 A61B2562/0247 A61H31/005 A61H31/007 A61H2031/002 A61H2201/5007 A61H2201/5043 A61H2201/5048 A61H2201/5061 A61H2201/5071 A61H2201/5079 A61H2201/5084 A61H2230/04 A61H2230/06 A61H2230/207 A61N1/39044 A61N1/3925 G16H15/00 G16H40/63 H01H2215/004		
优先权	10/609001 2003-06-27 US 10/704366 2003-11-06 US		
其他公开文献	EP1491176A1		
外部链接	Espacenet		

摘要(译)

一种用于辅助救助者在受害者的CPR期间执行胸部按压的装置，该装置包括垫或其他结构，该垫或其他结构被配置成施加到救护者施加力以产生胸部按压的位置附近或位置处的胸部，至少一个传感器连接到垫，传感器被配置为感测胸部的运动或施加到胸部的力，处理电路用于处理传感器的输出以确定救助者是否在胸部按压之后基本上释放胸部，并且至少一个提示元件连接到处理电路，用于向救助者提供关于胸部按压后胸部是否基本上被释放的信息。